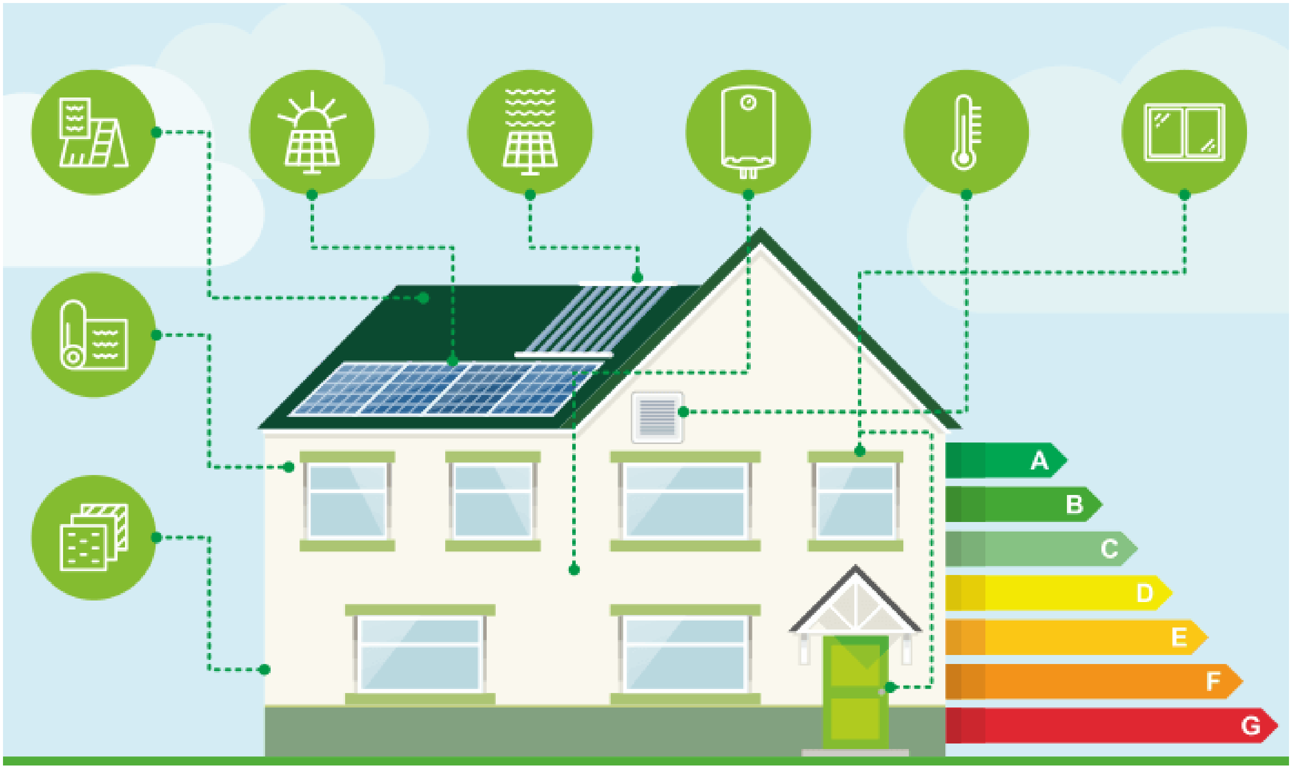
# Saving Energy and Reducing Greenhouse Gases in Single-Family Houses in Fløng

Master Thesis in MSc. Techno- Anthropology

Aalborg University Copenhagen

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## Abstract

Denne rapport omhandler energirenovering og varmeforsyning i Fløng. Her er der kigget nærmere på lovgivningen inden for området, Høje Taastrup Kommune og bæredygtighed, samt samspillet mellem kommune og borger. Det genereret empiriske data i denne rapport er hovedsageligt gennem interviews. De metodiske tilgange i rapporten har været semistrukturerede interviews, kodning og personas. Det teoretiske skelet i rapporten er aktør netværksteori i særdeleshed Michel Callons *Four Moments of Translations*, for at analysere det empiriske materiale fra borgerne i Fløng. Konklusionen på rapporten er at der et ustabilt netværk mellem kommunen og borgerne, her er det tydeligt at der mangler en talsperson. Derudover mangler der konsensus omkring temaer som økonomi, informationer og i de forskellige energiløsninger. Boligejerne skal også selv på banen, for at samspillet mellem borgere og kommune kan optimeres. Derudover er der skabt personaer til Høje Taastrup Kommune, så de lettere kan tilgå borgerne i Fløng i forhold til varmeforsyning og energirenovering i området.

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# 1.0 Introduction

Today it is widely agreed that carbon emission, inflicted by humans, is the main cause of climate changes around the globe (Allen et al. 2009; Matthews et al. 2009; Goodwin, Williams and Ridgwell 2014). Since the 1880-1920 era, the global surface temperature has continuously increased with the years 2015-2018 being the four warmest. During this period, the temperature has increased by 1,1 degrees Celsius in total and 0,9 degrees Celsius since 1970 (Hansen et al. 2019). The changes in global surface temperature are directly connected to the cumulative carbon emission, thus greenhouse gas emissions need to be reduced to stop or reverse the tendency in global surface temperature changes (Frölicher and Paynter 2015).

The global consumption of fossil fuels has over the last 200 years increased rapidly, which leaves the global fossil fuel reserves depleted ("The End Of Fossil Fuels" 2020). The outcome of the depleting fossil fuel reserves is that fossil fuel reserves are harder to come by, as the fossil fuel reserves do not last forever ("The End Of Fossil Fuels" 2020). Ultimately, it means that we are facing a scenario where the global fossil fuel reserves are running out, and thus we need alternatives energy sources ("The End Of Fossil Fuels" 2020).

In 2015, the member states of the United Nations agreed to commit to an ambitious common effort to keep the global temperature rise in the 21st century well below 2 degrees Celsius compared to pre-industrial levels and preferably not above 1,5 degrees Celsius (United Nations, 2015).

The Danish contribution to this commitment is an agreement to pass a new climate legislation, to reduce the country's greenhouse gas emission by 70%, compared to 1990 levels, no later than 2030, and to be fully climate neutral no later than 2050. In the time of writing, the bill has been passed in the parliament but has yet to be written and effectuated (Klima-, energi- og forsyningsministeriet 2019). To accommodate this future legislation, the local administrations around Denmark must take action on how to reduce greenhouse gas emissions within the respective municipalities. 84 of 98 municipalities already have a climate plan and have already taken action to reduce their carbon emission. Possible actions to initiate by the municipalities could be e.g. garbage sorting, infrastructure, or sustainable public buildings ("Hvad Gør Kommunerne?" 2020).

In 2015, the municipality of Høje Taastrup published a 2020 climate plan, which is now due to be revisited (Høje Taastrup Kommune 2015). In this regard, the authors of this thesis were invited to a meeting at the technical- and environmental department at the city hall of Høje Taastrup, to discuss the possibilities of conducting techno-anthropological research within one of the fields of which the municipality was planning to take actions to reduce carbon emission. It quickly became clear, that the field with the most techno-social issue, was the field dealing with heating supply in private residences. The representatives from the technical- and environmental department at Høje Taastrup Municipality informed that most private single-family houses in some of the outer parts of the municipality of Høje Taastrup rely on a heat supply based on fossil fuels. At the meeting, the representatives of the technical- and environmental department informed, that it seemed that the house owners tend to be hesitant when it comes to replacing their current heat supply with a more sustainable solution. Since there is a great potential to reduce greenhouse gas emissions by replacing the heat supply in private residences to more sustainable solutions, the technical- and environmental department are interested in gaining knowledge about how the municipality can play a role in replacing heat supplies in the local private single-family houses.

To investigate this, the authors of this thesis turned to a local community in the municipality of Høje Taastrup called Fløng. Fløng is a small town consisting mostly of single-family houses of which most still have a heat supply based on fossil fuels, predominantly natural gas, or oil.

## 1.1 Sustainability

In 1987 the famous UN Brundtland report, called "*Our Common Future*", the term sustainable development was defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* (United Nations sustainable development, n.d.). The "Brundtland" definition is the most common definition used. However, the Brundtland definition of sustainability is today considered to be vague as the interpretation of the definition is based on how one considers sustainable development itself (Bjerregaard and Arrouas, 2013).

### 1.1.1 Weak and Strong Sustainability

According to Bjerregaard and Arrouas, there are generally two different perceptions of sustainability, weak sustainability, and strong sustainability (Bjerregaard and Arrouas, 2013).

In weak sustainability, the most important thing is that natural capital is replaced by man-made capital (Bjerregaard and Arrouas, 2013). This interpretation of the concept of sustainability, therefore, emphasizes that one can deplete natural resources and destroy ecosystems if it supports economic growth and technological development and thus does not compromise future generations (Bjerregaard and Arrouas, 2013). According to Bjerregaard and Arrouas, the proponents of weak sustainability would advocate for extracting the natural resources as it would create man-made capital (Bjerregaard and Arrouas, 2013). According to the proponents of weak sustainability, the natural capital is equal to man-made resources (Bjerregaard and Arrouas, 2013).

In strong sustainability, the most important thing is that the development must not lead to irreparable loss of natural resources (Bjerregaard and Arrouas, 2013). A very restrictive interpretation of strong sustainability is that all forms of capital, both natural and man-made, must be kept separate from one another and cannot replace each other or by anything else (Bjerregaard and Arrouas, 2013). Bjerregaard and Arrouas give an example of strong sustainability, where a small forest is felled in order to build a cottage, in terms of strong sustainability, the cottage can never be sustainable, as natural capital was destroyed in order to build a cottage, which is considered as man-made capital (Bjerregaard and Arrouas, 2013).

### 1.1.2 Three Pillars of Sustainability

According to Matthew Mason, the World Summit on Social Development identified three core areas that contribute to the philosophy and social science of sustainable development back in 2005 (Mason, n.d.). Mason describes these three core areas as the three pillars of sustainability. The three pillars of sustainability as; e*conomic development*, *social development*, and *environmental protection* (Mason, n.d.).

Economic development is about providing enticements for the average person as well as for businesses and other organizations to follow the sustainability guidelines (Mason, n.d.). According to Mason economic development is one of the most debated pillars, as there is a lot of politics and ideology involved in this topic, which means how these sustainability guidelines are followed, is very different from country to country (Mason, n.d.). Mason sums up the economic development as giving people what they want, in terms of consumables, without compromising the quality of life (Mason, n.d.).

In social development, the most important thing is the awareness of the legislation that protects the health of people from pollution and other harmful activities which businesses and other organizations cause (Mason, n.d.). According to Mason, in the modern world, there are many checks and legislation program to make sure that the health and wellness of the people is protected (Mason, n.d.). Social development is also about maintaining access to basic resources without compromising the quality of life (Mason, n.d.).

Environmental protection is all about protecting the resources of the earth (Mason, n.d.). According to Mason, this pillar is about protecting the environment by recycling, reducing the power consumption as well as reducing usage of fossil fuels (Mason, n.d.). In short environmental protection is all about changing human behavior e.g. instead of taking the bus or car to travel a short distance, walk. Businesses are also regulated to prevent pollution and to keep their carbon emission low (Mason, n.d.). Furthermore, by using renewable power sources in homes and businesses, the carbon emission could be significantly lowered (Mason, n.d.). The primary concern is the future of the humanity and developing technology that can replace the usage of fossil fuels (Mason, n.d.).

### 1.1.3 Green Transition

Green transition is the term for the transition from the current "black" energy sources that are based on fossil fuels, such as coal, gas, and oil to green energy that is based on renewable energy sources (Bjerregaard and Arrouas, 2013). The world is currently going through a green transition. Due to the climate changes being so catastrophic, an urgent plan of the transition of fossil fuels to renewable energy is essential in order to slow down the effects of the global climate crisis (Bjerregaard and Arrouas, 2013). The green transition is not only about using renewable energy sources, it is also about changing human behavior and the current pattern of energy consumption (Bjerregaard and Arrouas, 2013).

According to Bjerregaard and Arrouas, the climate commission that was pointed out by the former Danish prime minister Anders Fogh-Rasmussen identified that the transition must primarily be done by energy efficiency improvements and a conversion to renewable energy sources, such as biomass, wind energy, geothermal heat, etc. (Bjerregaard and Arrouas, 2013). By using energy more efficiently and restructuring the electricity production, the demand for fossil fuel will decrease (Bjerregaard and Arrouas, 2013). According to Bjerregaard and Arrouas, in 2018 the renewable energy accounted for 37 % of the total energy consumption in Denmark (Bjerregaard and Arrouas, 2013).

The green transition is a vision of a cleaner world without pollution and a sustainable use of natural resources, without compromising the quality of life as we know it today (Bjerregaard and Arrouas, 2013).

## 1.2 Paris Agreement

This section will present the political aspect of climate change from an international level, looking into the Paris agreement from 2015, to a national and local level, looking into the Danish 2030 and 2050 goals and how they affect the municipalities throughout the country.

COP21 was held in Paris in 2015, where 195 countries tried to come to an agreement. The topic of the meeting was the climate change and how countries should adapt to those changes ("Paris Agreement - Climate Action - European Commission" 2020). The Paris agreement contains a global goal, which is to avoid dangerous climate changes by limiting global warming to below 2 degrees Celsius compared to pre-industrial level, additionally pursuing an effort for limiting global warming to no more than 1.5 degrees Celsius ("Paris Agreement - Climate Action - European Commission" 2020). Furthermore, the Paris agreement aims to strengthen countries' ability to handle the impact of climate change. According to IPCC, the global temperature can increase by 4 degrees Celsius at the end of this century if there is not a change in greenhouse gas emissions ("Femte Hovedrapport Fra IPCC" 2014). In the element of mitigation, the countries agreed on:

- *"A long-term goal of keeping the increase in global average temperature to well below 2°C above pre-industrial levels.*
- *To aim to limit the increase to 1.5°C, since this would significantly reduce risks and the impacts of climate change.*
- *On the need for global emissions to peak as soon as possible, recognising that this will take longer for developing countries.*
- *To undertake rapid reductions thereafter in accordance with the best available science, so as to achieve a balance between emissions and removals in the second half of the century".*

Data from ("Paris Agreement - Climate Action - European Commission" 2020)

Furthermore, the countries agreed on more transparency, hence have a meeting every 5th year, reports and through tracking of the progression they have made ("Paris Agreement - Climate Action - European Commission" 2020). They agreed on strengthening societies that have the ability to deal with the causes of climate change and therefore continue to enhance the support for climate adaptation to developing countries ("Paris Agreement - Climate Action - European Commission" 2020).

They agreed following on loss and damages:

- *"Recognises the importance of averting, minimising and addressing loss and damage associated with the adverse effects of climate change.*
- *Acknowledges the need to cooperate and enhance the understanding, action and support in different areas such as early warning systems, emergency preparedness and risk insurance".*

Data from ("Paris Agreement - Climate Action - European Commission" 2020)

The agreement illuminates the role of other stakeholders and invites every non-party stakeholder to optimize their reduction on the imprint of greenhouse gas emission ("Paris Agreement - Climate Action - European Commission" 2020).

## 1.3 Danish Political Climate Goals

In this section, the Danish climate goals will be presented. This section will focus on the ongoing climate legislation agreement which is described as the 2030 goal. Furthermore, a short presentation of the Danish 2050 goal will be given.

### 1.3.1 Climate Legislation Agreement – Climate Goals 2030

The Danish parliament have agreed that Denmark should work toward the goal of keeping the global rise of temperature down, to a maximum increase of 1.5 degrees Celsius ("Danmark Har Fået En Aftale Om En Ambitiøs Og Bindende Klimalov", 2020). This goal was agreed upon due to the COP21 meeting in Paris ("Danmark Har Fået En Aftale Om En Ambitiøs Og Bindende Klimalov", 2020).

The political parties have agreed that Denmark must have binding climate legislation with an ambitious goal of a 70 % reduction of greenhouse gas emissions in 2030 compared to 1990 ("Danmark Har Fået En Aftale Om En Ambitiøs Og Bindende Klimalov", 2020). Furthermore, the agreement acknowledges a long-term goal of climate neutrality by 2050 ("Danmark Har Fået En Aftale Om En Ambitiøs Og Bindende Klimalov", 2020).

The achievement of Denmark's climate goals must be as cost-effective as possible, without compromising the Danish welfare and companies ("Danmark Har Fået En Aftale Om En Ambitiøs Og Bindende Klimalov", 2020). Furthermore, the agreement states that the greenhouse gas emission reduction must be national, and the greenhouse gas emissions cannot be outsourced from Denmark to another area or country ("Danmark Har Fået En Aftale Om En Ambitiøs Og Bindende Klimalov", 2020).

The Climate Legislation Agreement can be found in Appendix 1

### 1.3.2 Climate Action Plan – May 20, 2020.

On Wednesday, May 20, 2020, the government presented its proposal for a climate action plan in relation to the 2030 goal of reducing greenhouse gas emissions by 70 % in 2030 (Petersen, 2020). The government presented six specific actions that they propose to carry out to achieve the 2030 goal of a national greenhouse gas reduction (Petersen, 2020).

The government's proposal of climate actions can be seen below:

1. **Energy Islands**
    a. According to Petersen, the government proposed that instead of the well-known offshore wind farms, the establishment of two new so-called energy islands should be done (Petersen, 2020). By 2030, an artificial island must be established in the North Sea, and one in the Baltic Sea. Each of them must have a power of 2 GW (Petersen, 2020). Together, the two energy islands will produce twice as much energy as the currently operating windmill parks around Denmark (Petersen, 2020).

2. **Invest in Technology**
    a. The government is proposing to invest in green technological solutions (Petersen, 2020). The government has a plan of investing 400 million DKK each year in new technology which can store carbon emissions (Petersen, 2020).

3. **Green Transition of the Danish Industry**
    a. The government points out that to achieve the 2030 goals, a green transition of the Danish industry is required (Petersen, 2020). The government has planned to invest 900 million DKK per year from 2020-2024 (Petersen, 2020).

4. **Energy Efficiency of Buildings and the Industry**
    a. The government will promote energy efficiency in buildings and the industry of Denmark (Petersen, 2020). Thus, funds must be allocated to collect and display data on buildings and their energy consumption (Petersen, 2020).

5. **Phasing out of Oil and Natural Gas**
    a. The taxes on “green power” must be lowered, while the taxes on “black power” must be raised (Petersen, 2020). Additionally, the government will invest 2.3 billion DKK, which will be used to replace oil and natural gas with green heating solutions (Petersen, 2020).

**6. Climate neutral waste sector by 2030**

a. According to the government plan, Denmark needs a climate-neutral waste sector by 2030 (Petersen, 2020). This means that around 80 % of the Danish waste plastic will be sorted out before incineration (Petersen, 2020).

The Climate Action Plan Can Be Found in Appendix 9

### 1.3.3 Danish Climate Goal 2050

According to the Danish Climate – Energy and Supply ministry, the long-term climate goal of Denmark is to become climate neutral, meaning a nation that does not emit more greenhouse gasses than what is absorbed by nature  ("Klimaindsatsen I Danmark", 2020).

As part of an energy agreement in 2018, a joint Danish parliament decided that Denmark should work toward a net-zero greenhouse gas emissions in accordance with the Paris Agreement ("Klimaindsatsen I Danmark", 2020). A society with net-zero emission of greenhouse gases is also referred to as a climate natural society, and this is what Denmark is aiming for by 2050 ("Klimaindsatsen I Danmark", 2020). By being climate neutral, no more greenhouse gases are emitted than absorbed, either by nature or by technological absorption of greenhouse gasses ("Klimaindsatsen I Danmark", 2020).

The Danish 2050 goal of becoming climate neutral is Denmark´s contribution to the European Union 2050 goal ("Klimaindsatsen I Danmark", 2020). In 2018 the European Union commission presented a vision, in which the whole European Union should be climate neutral by 2050 ("Klimaindsatsen I Danmark", 2020).

According to the Danish Climate- Energy and Supply ministry Denmark´s transition to renewable energy sources and development of climate technologies as a part of the 2050 goal, can help maintain Danish climate companies' reputation ("Klimaindsatsen I Danmark", 2020). The increasing global demand for green technologies will create growth and jobs in Denmark ("Klimaindsatsen I Danmark", 2020).

## 1.4 The Solar Panel Scheme

This section of the report contains a look into at the legislation of energy from solar cells and there have been episodes of changes in an extra charge for the energy made by solar panels.

In 2012 nearly 85.000 Danish households invested in solar cell panels, as a result of a new solar panel scheme. The scheme was that the solar cell panel owners could assess their consumption once a year (Lisby, 2018). This means that the extra power generated in the summer could be deducted from the consumption in the winter. The scheme saved the owners PSO-Fee, electricity fee, and value-added- tax (Lisby, 2018).

The Danish Energy Agency wants the solar cell panel owners to change towards another agreement, which will make it more expensive to have a solar cell panel installed. They closed the agreement from 2012, where they additionally promised that the agreement from 2012 would be valid in the next 20 years (Lisby, 2018). The only change with the agreement which was not incorporated at first is that the owners shall pay value-added-taxes more frequently than once a year (Lisby, 2018). The subsidy scheme for solar cell panels is two different subsidy schemes it is the net-fee and feed-in tariff. The net-fee covers the own production of energy, which is self -used and the owner does not pay taxes for this part (Iversen, 2013). Feed-in Tariff covers the part of production which is not self-used and part of overproduction.

The production of energy will be estimated on an hourly basis which will make it more expensive for the owners (Iversen, 2013). This could end with a decrease in solar cell installations, solar cell panels with adequate energy for their household and lastly the overproduction will be sold to the grid for 1,3 DKK/kWh opposite 2 DKK/kWh previous, were the solar cell panels were covered by the yearly net-fee (Iversen, 2013). The change in the agreement came because of the increase in capacity from the solar cell panels and therefore the politicians changed the agreement at the beginning of 2013 (Iversen, 2013). The changes of the agreement is a major debate, where solar cell owners have filed a suit against the Danish Energy Agency. The changes of the agreement have created distrust from the owners of solar cell panels and other people who intend to invest in other energy-friendly solutions as solar cell panels (Bruun, 2019).

### 1.4.1 Subsidy and Deduction

This section contains a brief view on subsidy and deduction from the government for individuals with environment-friendly initiatives.

There are two different contributions which are the deduction and energy subsidy, when citizens intend to renovate their house or change the heat supply for a more environment- friendly solution ("Tilskud Og Fradrag" 2020).

### 1.4.2 Subsidy from Energy Companies

This subsidy covers counseling, renovation, and replacement of heat supply ("Tilskud Og Fradrag" 2020). Through most of the energy renovation initiatives, there can be obtained economic support. ("Tilskud Og Fradrag" 2020). The size of the subsidy is dependent on how much energy is saved, what the house owner replaces, and which energy company it is ("Tilskud Og Fradrag" 2020).

### 1.4.3 Artisan Deduction

There is a possibility to get artisan deduction. This is done by the tax, where the artisans are covered when it is for energy renovation or climate initiative ("Tilskud Og Fradrag" 2020).

The deduction and subsidy can be used at the same time on the same renovation. Sometimes there can also be a national subsidy for instance to scrap the old oil-fired boiler, there can also be local subsidies ("Tilskud Og Fradrag" 2020). Beneath is a table of estimated subsidies for energy renovation

| **Energy Improvement** | Average Grant In DKK |
|---|---|
| **Insulation** | |
| Re-insulation of 140 m² unheated ceiling. From approx. 75 mm to approx. 275 mm. House heated with district heating. | 1.300 DKK |
| Insulation of 100 m² exterior walls from before 1972. Re-insulation with at least 95 mm. House heated with district heating. | 2.400 DKK |
| Re-insulation of 100 m² lightweight exterior walls. From 25-45 mm insulation to at least 145 mm. House heated with district heating. | 2.400 DKK |
| 18 m heat pipe with 0-25 mm insulation re-insulation to at least 30 mm. House heated with district heating. | 120 DKK |
| **Windows** | |
| 30 m² windows with 1-, 2- or 3-layer double glazing or single-layer windows replaced | 2.500 DKK |

| | |
|---|---|
| with A-labeled windows. House heated with district heating. | |
| **Heating** | |
| Change from electric heat to air to water heat pump or geothermal heating | 3.100 DKK |
| Change from electric heat to air to air heat pump | 650 DKK |
| Change from non-condensing oil boiler to district heating | 3.600 DKK |
| Change from oil furnace or natural gas with condensing boiler to district heating | 1.600 DKK |
| Change from non-condensing oil boiler to air to water heat pump or geothermal heating | 7.300 DKK |
| Change from oil boiler or natural gas with condensing boiler to air to water heat pump or geothermal heating | 5.400 DKK |

Table of estimated subsidy for energy renovation ("Tilskud og Fradrag", 2020)

## 1.5 Danish Heat Supply Legislation

In 1979 the first legislation concerning the heat supply in Denmark was implemented (Energistyrelsen, 2007). With the implementation of the "Heat Supply Act" a comprehensive heat supply planning was initiated (Energistyrelsen, 2007). Denmark was divided into supply areas, where urban areas became a part of a collective heat supply of either district heating or natural gas (Energistyrelsen, 2007). Areas with sparsely population continued with individual heat supply, such as oil (Energistyrelsen, 2007). The planning of the national heat supply was mainly completed in 1990. Since 2004 the municipalities in Denmark are in charge of approving the planning of the heat supply within the municipality itself, as it is the local council who makes the decision in relation to the heat supply planning and expansion of the heat supply within the municipality (Energistyrelsen, 2007).

The purpose of the heat supply act is to promote the most socio-economic and environmentally friendly use of energy for heating and supplying a building with hot domestic water (Energistyrelsen, 2007). In terms of the socio-economic calculations, a plan of the investment must include an array of expenses and revenue over time (Energistyrelsen, 2007). Fuel costs are typically a decisive factor as well as electricity sales from a power plant. According to the Danish Energy Agency they provide which prerequisites that must be the basis for the calculations, as well as the development in the fuel prices (Energistyrelsen, 2007). Additionally, The Danish Energy Agency provides the price on taxes on environmental effects, such as $CO_2$ and NOx, this means that projects are charged with a cost corresponding to the potential pollution of the project (Energistyrelsen, 2007).

The most beneficial project for society must be found with a socio-economic calculation (Energistyrelsen, 2007). A comparison between different possible heat supply solutions can show what project proposal is the most beneficial for society (Energistyrelsen, 2007).

In 1990 a new planning system was implemented called the project system (Energistyrelsen, 2007). As the overall frameworks and delimitations were settled, it was only necessary to assess new projects in relation to defined heat plans and defined prerequisites by The Danish Energy Agency (Energistyrelsen, 2007). The role of the Danish municipalities was to assess that the specific project proposals fulfilled the prerequisites set by the former ministry (Energistyrelsen, 2007).

According to The Danish Energy Agency the heat planning and project processing of municipalities must ensure that the purpose of the Heat Supply Act and the general energy political goals are accommodated (Energistyrelsen, 2007). Furthermore, the heat planning and project processing of the municipalities must specifically ensure the following:

- That there is up-to-date knowledge of the heat supply conditions as a basis for a heat supply restructuring
- That restructuring of the heat supply is initiated as per the local legislation and general prerequisites.
- That heat supply projects are conducted in accordance with social needs which are described in the prerequisites of the Danish Energy Agency.
- That the development of the connection to the collective heat supply in the municipality is followed and evaluated (Energistyrelsen, 2007).

The Heat Supply Act Can Be Found in Appendix 2

## 1.6 Høje Taastrup Municipality

Høje Taastrup Municipality is a municipality located approximately 20 kilometers away from the Danish capital Copenhagen (Welcome to Høje-Taastrup Municipality, n.d.). Høje Taastrup Municipality consists of smaller towns however, the three largest towns of Høje Taastrup Municipality are: Taastrup, Hedehusene, and Sengeløse. The Municipality of Høje Taastrup have a population of approximately 51,000 citizens. (Welcome to Høje-Taastrup Municipality, n.d.). According to Høje Taastrup Municipality, they are in the coming years ready to welcome more than 8,000 new residents in the municipality´s new upcoming urban areas (Welcome to Høje-Taastrup Municipality, n.d.). Høje Taastrup Municipality is one of the largest municipalities in Greater Copenhagen and is a part of The Capital Region of Denmark (Kommuner i Region Hovedstaden, n.d.).


*Outline of Høje Taastrup Municipality*

The Municipality of Høje Taastrup has a total area of 72 km² and has multiple train stations and good motorway connections throughout the municipality along with intercity, regional train networks, and bus services (Welcome to Høje-Taastrup Municipality, n.d.).

According to Høje Taastrup Municipality, the municipality is considered a large commuter municipality as around 25,000 people commute into the municipality during the week, these people commute to their jobs in one of the many companies that are based in Høje Taastrup Municipality (Welcome to Høje-Taastrup Municipality, n.d.). The municipality has large companies within IT and service, logistics, transport, and regional retail trading as well as knowledge-intensive companies and institutions (Welcome to Høje-Taastrup Municipality, n.d.).

According to Høje Taastrup Municipality, the municipality stands for professional and effective municipal services. Furthermore, the municipality wishes to provide services to residents that are based on openness, respect, and understanding of peoples' social and cultural backgrounds (Welcome to Høje-Taastrup Municipality, n.d.). The town council consists of 21 democratically elected members and the current Mayor is Michael Ziegler from the political party Conservative (Welcome to Høje-Taastrup Municipality, n.d.).

Høje Taastrup Municipality offers schools and childcare institutions in every urban area of the municipality. Furthermore, the municipality encourages its citizens to an active lifestyle as the municipality offers a variety of sports clubs and sports facilities along with libraries and cultural institutions. Additionally, in Høje Taastrup Municipality there is easy access to more than 30 nature and park areas with great nature and recreational facilities (Welcome to Høje-Taastrup Municipality, n.d.).

### 1.6.1 Høje Taastrup Municipality: Strategic Energy and Climate Plan 2020

**This report was published in 2015 and is valid through 2020.**

According to the Mayor of Høje Taastrup Municipality, Michael Ziegler, the global climate crisis is caused by anthropogenic activities and the consequences of these activities are indeed noticeable around the planet, and therefore it is time to act now (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). Furthermore, the Mayor, says that in Høje Taastrup Municipality the green transition goes hand in hand with economic growth and in order to achieve the municipal goals it is crucial to develop and implement green solutions within the municipality itself and among citizens and companies in the municipality while simultaneously creating new jobs in the municipality (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015).

According to the report:" Strategisk *Energi- og Klimaplan 2020"* (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). The Municipality of Høje Taastrup has since 2008 been focused on promoting environmentally friendly district heating along with energy renovation of municipal buildings, private single-family houses, and apartments. Furthermore, the municipality, in 2008, started to change its municipal vehicle fleet to electric vehicles (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). In "*Stategisk Energi- og Klimaplan 2020"* the municipality of Høje Taastrup presents the framework, guidelines, and priorities in relation to future energy and climate effort (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015).

### 1.6.2 Summary of the Report

This report is a direct follow up to the last energy and climate plan from 2009-2014 (Appendix 3, p 11.), in which every goal has been well achieved (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015).

Høje Taastrup Municipality´s visions in this 2020-report are very clear: Høje Taastrup Municipality must become fossil-free by 2050 (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). According to the municipality the goal of becoming fossil-free by 2050 is going to be achieved through a cost-effective green transition of the electricity, heating, and transport sections which will benefit the environment, citizens and companies in the municipality (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015).

In this report, the municipality focuses on four areas: *energy efficiency*, *electricity supply, heat supply*, and *transport* (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). According to the report, the relation between human behavior and the technological development will be essential in order to achieve the goal of becoming fossil-free by 2050 (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). One of the goals is to reduce the municipal $CO_2$ emissions by 3% each year (from 2015) by 2020 (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015).

Climate approaches in terms of energy efficiency include every category of buildings in the municipality (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). Approaches like energy renovation of municipal buildings, implementation of a new internet portal in relation to energy consumption, reducing energy consumption specifically on single-family houses along with agreements with companies about reducing their energy consumption (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015).

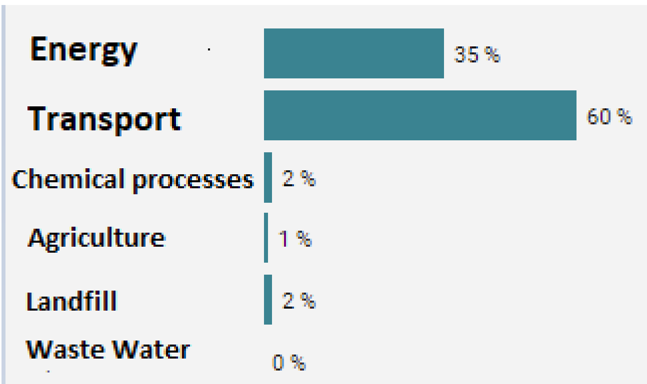
The municipality of Høje Taastrup has plans about phasing out oil and at some point, also natural gas as heating supplies (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). In order to achieve the goal of becoming fossil-free by 2050 oil and natural gas must be phased out in terms of heating households (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). The municipality plans on several actions in relation to an expansion of the district heat supply, e.g. better use of the district heating, implementing more renewable energy sources in district heating along with better utilization of surplus heat in terms of the district heating supply (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). Additionally, the municipality will provide information to residents and companies that are not a part of the collective heat supply (Høje Taastrup Kommune- Teknik- og Miljøcenter, 2015). The Strategic Energy and Climate Plan 2020 overall support sustainable urban development in the municipality.

Høje Taastrup Municipality is currently working on a new climate plan which will deal with the government's goal of reducing carbon emissions by 70% by 2030. The next climate plan will be available at the end of 2020.

### 1.6.3 Energy Consumption Data from Høje Taastrup Municipality

In this section, an overview of the energy and carbon emission numbers from 2017 of the municipality of Høje Taastrup will be presented.

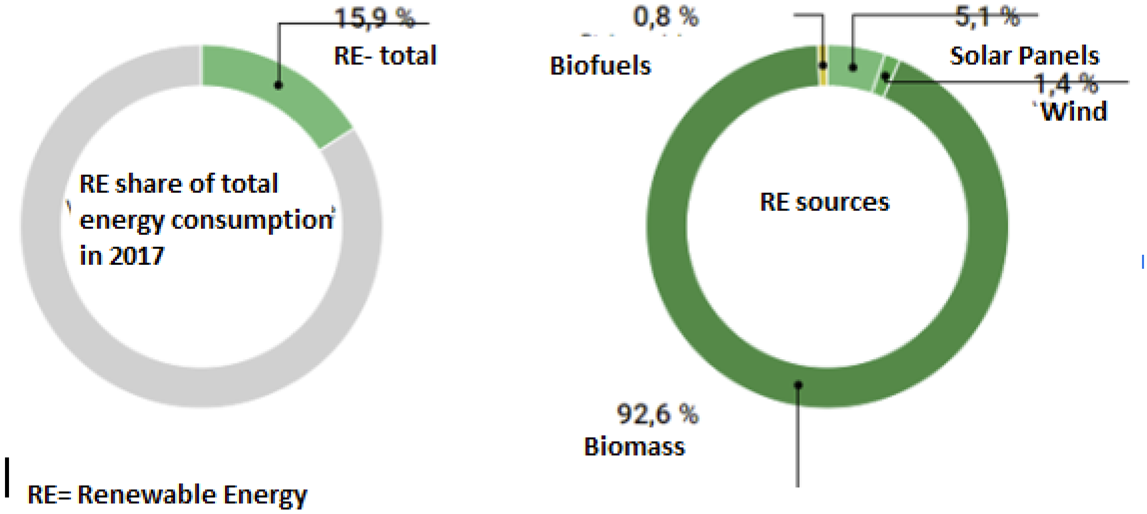
According to the data from the Danish Energy Agency, the municipality of Høje Taastrup have a total $CO_2$ emission of 329.513 tons ("Høje-Taastrup", 2020). The carbon emission that Høje Taastrup Municipality emits is distributed as follows:




The statistics above show that the energy consumption accounts for 35 % of the total $CO_2$ emission of Høje Taastrup Municipality ("Høje-Taastrup", 2020). This means that the energy consumption in Høje Taastrup Municipality emits around 115.020 tons of $CO_2$ per year ("Høje-Taastrup", 2020).

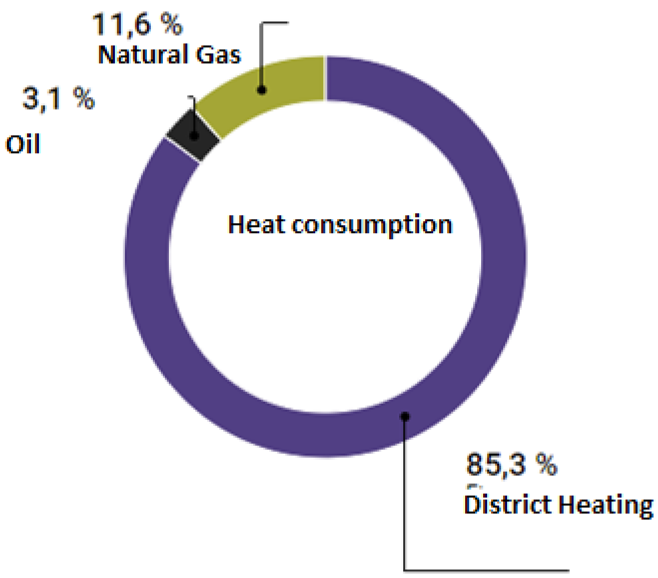
Based on these 115.020 tons of $CO_2$, the energy consumption emits 33.361 tons $CO_2$ ("Høje-Taastrup", 2020).

The illustration above shows that around 15.9 % of the total energy consumption is based on renewable energy sources:



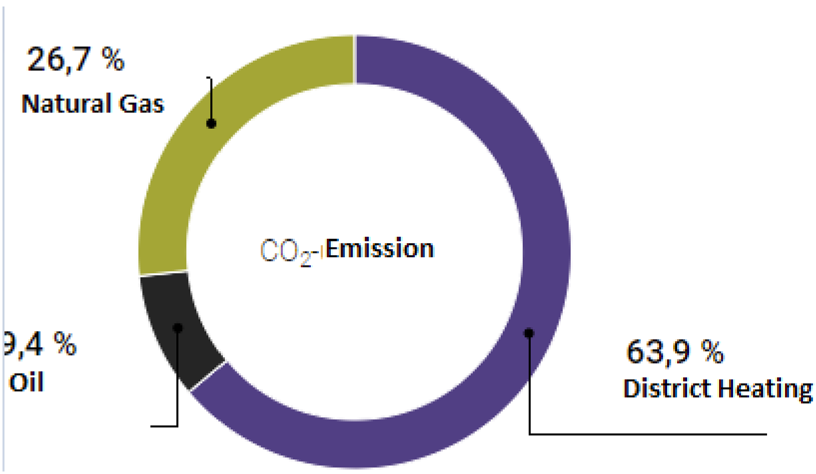

Additionally, the illustration above, shows that 92.6 % of the renewable energy source is based on biomass, whereas 1,4 is based on wind, and 5.1 % is based on solar power. Lastly, 0.8 % is based on biofuel ("Høje-Taastrup", 2020).

The illustration below illustrates the heat consumption based on the heat supply used in Høje Taastrup Municipality:




The illustration above shows that around 85.3 % of the heat consumption in Høje Taastrup municipality are based on district heating and that 11.6 % of the heat consumption is based on natural gas, whereas 3.1 % of the heat consumption is based in liquid fuel ("Høje-Taastrup", 2020).

The illustration below shows $CO_2$ emission based on the different heat supply solutions:




The illustration above shows that natural gas emits 26.7 % tons of $CO_2$ of the total $CO_2$ emission on 33.361 in the energy consumption of a common household ("Høje-Taastrup", 2020). Additionally, it shows that district heating emits 63.9 % of the total $CO_2$ emission whereas, liquid fuel emits 9.4 % of the total emission ("Høje-Taastrup", 2020).

## 1.7 The Fløng District

Fløng is a former village, which is now a part of the larger town Hedehusene in Høje Taastrup municipality (Fløng | Gyldendal - Den Store Danske, 2013). Today Fløng consists of many neighborhoods with single-family houses. Most of these single-family houses were built in the late 1960´s and throughout the 1970´s (Fløng | Gyldendal - Den Store Danske, 2013). The residents of Fløng consists of a mix between old retired people and a younger modern generation.


*Illustration of Fløng (Spatial Map, n.d.)*

### 1.7.1 Heat Supply in Fløng

Fløng consists of neighborhoods with single-family houses which can be seen in the illustration beneath. Most of the single-family houses in Fløng uses natural gas as the primary heat supply. The illustration underneath provides an overview of the heat supply in Fløng:


*Illustration of Fløng (Spatial Map, n.d.)*

In December 2011, a project about implementing district heating in Fløng was proposed as a part of Høje Taastrup Municipality´s climate plan 2009-2012 (COWI A/S, 2011). The project proposal included the establishment of district heating supply for homes, schools, and other institutions in Fløng (COWI A/S, 2011). The project aimed to supply almost 600 households in Fløng with district heating with an obligation to commit to district heating for nine years (COWI A/S, 2011). The project proposal was in accordance with the legislation on heat supply and requirements for being socio-economic beneficial (COWI A/S, 2011). The aim of the project was to convert natural gas users to district heating as part of a municipal climate plan (COWI A/S, 2011).

According to the project proposal, the user economy would benefit by converting to district heating. In the calculation provided in the Cowi report, an overview of the economy of heat supply based on natural gas, oil, and district heating is given, which shows that there is a significant financial benefit per year when choosing the district heating solution (COWI A/S, 2011).

The economic calculation can be seen below (COWI A/S, 2011):

**All amounts are including VAT**

Continued natural gas

| | DKK | DKK / Year |
|---|---|---|
| Investment new kettle (5 %, 20 years) | 40.000 | 3.210 DKK |
| Gas consumption (18,1 MWh - 90% m3 | 1.828 | |
| variable gas price DKK/ m3 | 8.812 | 16.114 |
| Settlment contribution | | 120 |
| Service agreement | | 1.875 |
| **Total natural gas price** | | 21.319 |

Continued oil heating

| | | DKK / Year |
|---|---|---|
| Investment new kettle (5 %, 20 years) | 50.000 | 4.012 |
| Oil consumption (18,1 MWh- 90 %) in liter | 2.033 | |
| Oil price per 1.000 liters | 10.300 | 20.940 |
| Service and chimney sweeper | | 1.500 |
| **Total oil price** | | 26.452 |

District heating

| | | |
|---|---|---|
| Pipe contributions | 15.250 | |
| Investment contribution | 3.424 | |
| New district heating unit and decopling of natural gas | 26.900 | |
| Investment total ( 5 %, 25 years) | 45.574 | 3.234 |
| Subscription | | 1.170 |
| Power tax (130 m2 - 17,75 DKK / m2 | | 2.308 |
| variable consumption | | |
| 18,1 MWh, 551,33 DKK / MWh | | 9.979 |
| Maintenance of district heating unit | | 625 |
| **Total district heating including decoupling** | | **17.316** |
| **Total district heating without decoupling** | | **17.363** |
| **Benefit district heating compared to natural gas** | | **4.003** |
| **Benefit district heating compared to oil heating** | | **9.089** |

*Financial calculations of implementation of district heating in Fløng (COWI A/S, 2011). Prices in the table above are based on prices from 2011*

In 2013 the project proposal was approved at the city council meeting on 28th May, however, with some big changes in relation to the initial plan (Fjernvarme Vestlige del af Fløng, 2013). The initial plan was to implement district heating in all of Fløng, however, this was not the case when it was approved by the city council in 2013 (Fjernvarme Vestlige del af Fløng, 2013).

District Heating was approved for the western part of Fløng, where most of the municipal properties are, such as schools, etc. The area where district heating was implemented can be seen below:

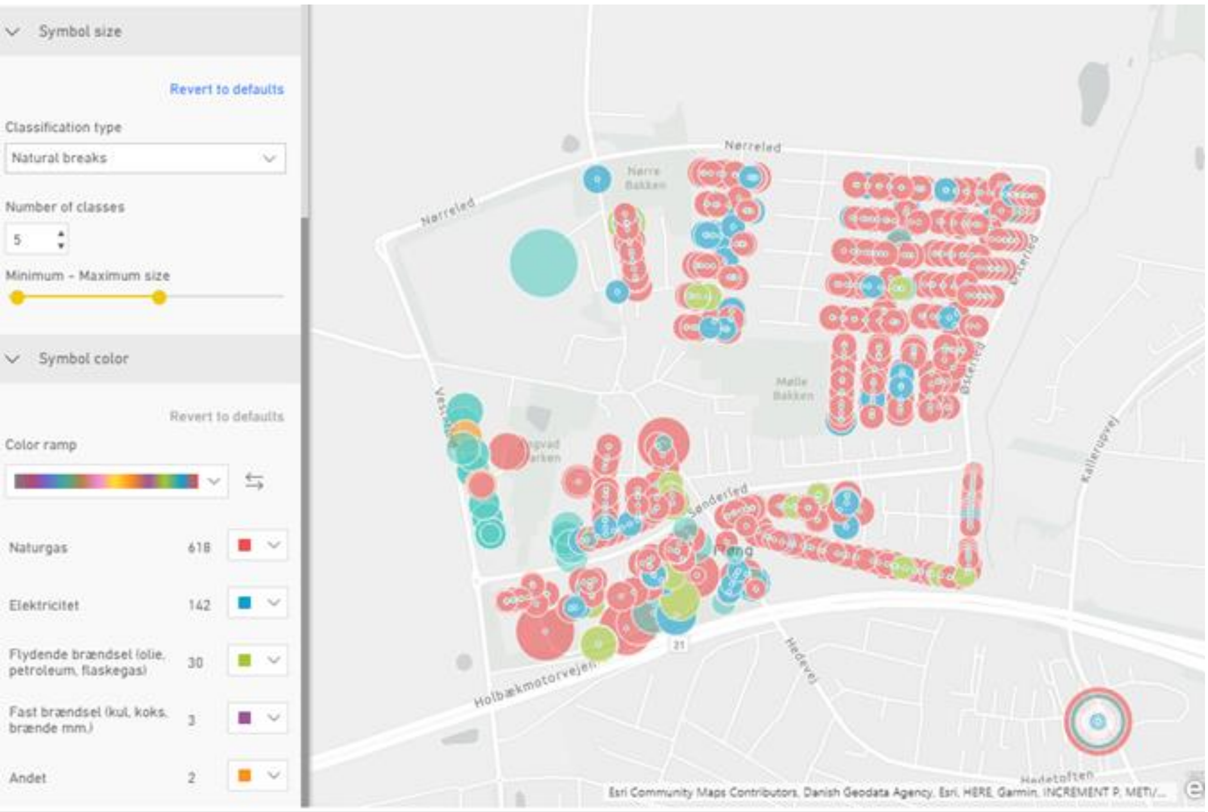
*Illustration of western Fløng where district heating was approved*

The project proposal that was approved, did not include a requirement of connection to district heating, which meant that after the approval of the project proposal owners of a building is free to choose what type of heat supply they wish to use (Fjernvarme Vestlige del af Fløng, 2013).

In addition to the establishment of a district heating distribution grid, one to two solar heating plants were approved (Fjernvarme Vestlige del af Fløng, 2013). One plant on the municipal-owned area west of Vesterled and one smaller plant near the Engvadgaard building, if residents wish this (Fjernvarme Vestlige del af Fløng, 2013).

### 1.7.2 Overview of non-District Heating Users in Fløng

Høje Taastrup Municipality provided us with an Excel spreadsheet with data containing every non-district heating connected house registered in Fløng and based on the excel sheet the following map has been made to give an in-depth view of how different types of heat supplies are spread out within the city of Fløng:




*Overview of alternative heat supply to district heating in Fløng.*

Based on the Excel spreadsheet provided to us by the Environment Department of Høje Taastrup Municipality, about 618 houses in Fløng use natural gas as their primary heat supply. Furthermore, 142 houses in Fløng use electricity as their primary heat supply. Moreover, 30 houses in Fløng use liquid fuel, such as oil as their primary heat supply. Three houses in Fløng uses solid fuel as their primary heat supply.

**Why did We Choose Fløng?**

Through our meetings with Høje Taastrup Municipality where we introduced to the area of Høje Taastrup and which small areas towns who were a part of the municipality. The area of Fløng was interesting because it was an area for itself and therefore was it more dependent on the involvement of the citizens. Furthermore, Fløng was interesting because there have been former similar initiatives in the area which have not elapsed as expected. Lastly was Fløng interesting because we intended to investigate an area that was more limited than all of Høje Taastrup Municipality to create a more exhaustive investigation of the field of energy-friendly initiatives.

## 2.0 Limitations

This section of the report deals with the selected limitations throughout the drawing up of the project and how these selections impacted the direction of the project.

Throughout the project, the authors of the thesis do not illuminate water- and electricity consumption, because we perceive water and electricity consumption as more practice-oriented elements that would change the examination towards the behavior and practices of the house owners. Furthermore, solar panels initiatives have not been illuminated because of their part in energy renovation, and we limited them, because of the decrease in them and the limited influence house owners have on solar panels. Additionally, we intended to investigate the heat supply and thereafter implicate renovation as a result of the apparent influence it has on heat supply and reduction in greenhouse gasses. We limited the geographical investigation to the area of Fløng to create more in-depth qualitative data instead of all of Høje Taastrup Municipality, besides understanding the house owners in Fløng in a broader manner.

Lastly, we limited us towards Fløng because of the unsuccessful implementation of district heating in Fløng to comprehend the reasoning behind this rejection. Throughout the project, we limited us to house owners because we assumed that house owners could choose more freely than citizens who live in public buildings, where the municipality has more power opposite house owners. Therefore, we limited to house owners to scrutinize the interplay that could occur between house owners and the municipality. For this reason, we examined the house owners and their needs. Therefore, we limited our focus towards the motivation for a change within the house owners instead of using calculation of $CO_2$ reduction and cost savings with a specific implementation.

Through this report the authors of the thesis describe greenhouse gas emissions. The authors are aware that greenhouse gases are an umbrella term for the gasses that affects the ozone layer. The different gases are e.g.: Carbon Dioxide, Methane, Nitrous Oxide, and water vapor (“Temaforside: drivhusgasser”, 2020). Throughout this report, different terms will be uses, dependent on the context. E.g. if an informant or the literature described says $CO_2$, that is the term being used in that particular context.

## 3.0 Problem Statement

This section of the report contains the problem statement, where we, through the introduction and the occurred issues within topics as sustainability, politics and Høje Taastrup Municipality arrived at the following problem statement within the field of heat supply and energy-renovation in Fløng.

As a Techno-Anthropologist working with user involvement is essential and therefore it is apparent for a Techno-Anthropologist when the interplay between user and developer is lacking. Based on previous sections the following problem statement has been made:

**How can municipal greenhouse gas reduction and energy-saving projects in Fløng, targeted single-family houses, accommodate the needs of the house owners through user involvement, and how can the Municipality of Høje Taastrup improve and promote user involvement.**

To answer the problem statement, Techno-Anthropological methods will be applied to collect data and analyze it through relevant socio-technical theoretical framework, which will be described later. The aim of this thesis is to understand and investigate the potential implementation of heat supply and energy-renovation in Fløng.

# 4.0 Literature Review

This section of the report revolves around previous studies of the field we intend to work in. This literature review contains different aspects of the field and we intend to use this section of the report to understand and map the given field, and furthermore look into how our report can answer some of the common questions in the field of energy consumption in single-family houses in Denmark.

One of the first reports we read to understand our field was from “Fjernvarme uden rør” by Exergi Partners in 2015. This report was ordered by Høje Taastrup Kommune to understand how citizens could energy renovate their homes to a more energy-efficient home. The report illuminates the relation between customer and operator, where they conclude that operators should make heat supply as simple as possible, and instead of something which could disturb the citizens, they needed to change it to service instead. The report puts a focus on the simple process that the customer needs to go through when they buy a more $CO_2$- friendly device. Lastly, the report gives a different perspective on the economy, where they claim that the municipality can not reach its goals if the energy renovation has a negative financial influence on the customers.

This report gave us a greater understanding of how users think and how to understand the steps that the municipality could take. Furthermore, the report gave us an understanding of which topics users focus on and hence what could be interesting to dig deeper into. The method ‘district heating without pipe’ could be an interesting approach to the field, because it creates a different relation between customer and operator, where the responsibility lies on the operator, and therefore it ends as a service for the customer. Lastly, this report helps us to understand the users of the area of Høje Taastrup Municipality and therefore map an approach for us.

Another interesting text we have read to understand our field is ‘Socioeconomic potential for introducing large-scale heat pumps in district heating in Denmark’ from 2016. We mainly looked into the first part of this two-folded report which is about the assessment of the economic potential for the introduction of heat pumps in Danish households. The second part of the report was using two different tools to develop energy systems to identify the optimal capacities of heat pumps. The Tool used in this report for energy system analysis was EnergyPLAN and MODEST. This study gave us a broader understanding of the technical part of a heat pump, and how they technically could use analysis models to calculate energy optimal capacities of heat pumps. The report gave us insights into the implementation of heat pumps in Danish households, and how heat pumps could be beneficial in the long run.

The following text from COWI with the title ‘ Fremtidens Varmeforsyning’ from 2018 is about the potential of district heating in Copenhagen. The report illuminates the financial element of district heating and how it is more cost-effective in some areas of Copenhagen and less cost-effective in other areas. The report from COWI clarifies how much energy certain areas of Copenhagen use, and how district heating could be beneficial in some areas and not that much in other areas. This report gave us insight in the technical element of energy in family houses, and how the electricity network is influenced by the geographical area where the investigation takes place.

Heat Roadmap Europe: Combining district heating with heat savings to decarbonize the EU energy system from 2014 is about different strategies for energy systems in a European Commission's report made by the EU. The idea behind these strategies is to identify possibilities to reach the target of 80% reduction in annual greenhouse gas emissions in 2050 compared to 1990 levels. In this report, they illuminate the idea of district heating and how it could potentially be less costly and more effective if they remove the focus from the electrification of the heating sector to district heating. The results show that the EU could achieve the same reduction in primary energy supply and carbon dioxide emissions as the already existing alternatives, but on the other hand, they could reduce the cost with approximately 15 % with district heating.

This report gave us a greater understanding of how district heating could be more beneficial in the long run to achieve the goal of 80 % in annual greenhouse gas emissions in 2050. Furthermore, the report gave us the inspiration to look into district heating and how it potentially could be implemented in our researched area. The text gave us insight into the process of how a target or strategies from the European Union could potentially influence the approach of municipalities and lastly how major the issue of climate change is.

A study from Aalborg University with the title: ‘Renovation of a Detached Single-Family House into an Energy-Efficient Low Energy House’ by investigates the energy changes of a single-family house from 1970 in Denmark (Larsen et. al, 2011). The investigation is about the changes which could occur when they renovate the house to a class A energy label to examine the changes to a single family-house to reach the goal of a 78 % reduction in energy consumption. They ascertain a 69 % reduction in energy consumption after 6 months, more energy-efficient houses, and lastly a better heat recovery. The indoor environment in the house got improved a lot compared to what it was before. The text from Aalborg University made it more clear to us how renovation could occur in single-family- houses, additionally the text gave us a more specific comprehension of the changes which could occur to a single family-house, especially to reach the targeted reduction.

The text with the title: 'Energy renovation of single-family houses in Denmark utilizing long-term financing based on equity made by Kragh and Rose in 2011. This paper investigates an economic overview of opportunities for the energy renovation of single-family houses. The paper focuses on the economic aspect between energy-saving and repayment of investment. According to the paper, approximately 30 % of energy consumption in Denmark is used for space heating. Taking out the average remaining 20% equity in long-term property mortgage loans and utilizing it for extensive energy renovation improves both the economy and the extent of included measures. Therefore they investigated single-family houses and the economical part of a renovation. Where they conclude that the average renovation varied between €20,000 and 40,000 per single-family house. The study concludes that a renovation could give a positive economic balance for the homeowner dependent on the future energy price.

This paper gave us a better understanding of the economical aspect of a renovation in single-family houses and the role of the relation of energy savings and repayment investments. Where factors as energy prices and equity in finances could have a major role.

The following report from SBI with the title "Renovering af danske parcelhuse – eksisterende viden og nye erfaringer" in collaboration with Aalborg University. This report investigates the understanding of house owners and their motivation to energy renovate. Throughout the report, they focus on prior international scientific work and on which methods could occur for the household owners to renovate. They conclude that the direct method they use to inform the household's owners works as it should, but this method is resource-demanding therefore they suggest that they should investigate in collective processes. Furthermore, they conclude that the municipalities should work more network-oriented, where they involve citizens in other similar projects as efficiency improvements from rainwater. Lastly, they conclude that national politics do not look into how the members in a single-family household use their homes (practices), instead, they focus on the energy renovation part of the house(technical). This report gave us different insights on important stakeholders in the given field of energy renovation, however, it also created a broader focus on the collective processes in energy renovation and how collective methods could be beneficial for energy renovation. Lastly, it opened up for an understanding of the interplay needed between the municipalities, the state, utility companies, and the laws in the given field. Through the report, they illuminate that it is not because of the lack of information that individuals do not renovate, but rather on the different phases of life that the families are in. This opened up for a more holistic view on this project which indicates that there could be different approaches to the given field.

To understand our given field, we looked at the scientific work of Brian Vad Mathiesen who is an engineer and professor in sustainability. Through his scientific work, he illuminates the lack of information among inhabitants and that if an energy initiative sounds energy-friendly it is not always as energy-friendly as it sounds. He illuminates that society should work better together. Here the household which makes additional energy should be able to grant it to other buildings. Furthermore, he points out that households should not buy solar panels because they are too expensive. He advises that Danish households should change from natural gas to district heating which is a more energy-friendly alternative. Furthermore, he illuminates the different practices that save energy and lower energy consumption. The practice could for instance be to turn off the light when it is not needed. Lastly, Brian Vad Mathiesen points out that individuals should engage themselves in the debate of energy and consequently contribute to different initiatives. The point from Brian Vad Mathiesen gave us an understanding of the lack of knowledge there could be among the general population. Thus, the population should have the possibility to acquire the right information especially in preparation for heat supply change or energy renovation.

This literature review has given us a broader understanding of our field and which key factors as well as influential topics there is in energy reduction. The different reports gave us insights into concepts and areas which could be interesting to investigate and therefore the literature review helped us to map a different road than we first expected. Moreover, it gave us ideas of areas where we could use our background to illuminate this field in a different way. The accumulation of different investigations made us look into how we could use our skills to map out a different solution to understand how the occupant of single-family houses could accommodate the targeted reduction from the EU through the energy renovation of their house.

# 5.0 Technology

In this section the technological framework of this thesis will be described.

## 5.1 Energy Renovation of Single-Family Houses

This section will be about energy renovation of single-family houses. In this section, a short description of energy renovation will be presented. Next, a list of energy renovation initiatives provided by the Danish Energy Agency will be presented.

Energy renovation is about optimizing houses in order to reduce energy consumption and thus reducing carbon emissions. However, the byproduct of an energy renovation is in most cases better comfort (Hvad er energirenovering?, n.d.). An energy renovation results in energy savings, as well as indoor climate improvements (Hvad er energirenovering?, n.d.). In relation to energy renovation, the house owners are typically the most important actors, because the house owners themselves need to take initiative and invest in the energy renovation of their house (Hvad er energirenovering?, n.d.).

### 5.1.1 Single-Family Houses Built between 1960-1980

Single-Family houses were built between 1960s and 1980s (Parcelhus 1960 - 76, n.d.). Single-family houses became popular and thus a lot of single-family houses were built throughout Denmark. The single-family houses were built for a single-family and was just big enough to meet the needs of an ordinary family, which typically is two parents and two children (Parcelhus 1960 - 76, n.d.). The size of a typical single-family house is around 140 M² (Parcelhus 1960 - 76, n.d.). According to the Danish Energy Agency about half of the Danish single-family houses were built in the period of 1960 to 1980 (Parcelhus 1960 - 76, n.d.).

As mentioned earlier in this report most of the single-family houses in Fløng were built in the 1960s, 1970s and some of the newest houses were built in the 1980s. The fact that most single-family houses in Fløng were built in the 1960s and 1970s means that they were built according to the standards which were applicable at that time. Since 1960, a lot of things have changed, new technologies have been invented, optimized materials etc. This means that single-family houses in Fløng can be optimized to reduce the overall energy consumption. Energy renovation is an important parameter in terms of securing the future of the house and obtaining a healthy building that lasts for many decades more to come (Hvad er energirenovering?, n.d.).

### 5.1.2 Energy Renovation Initiatives on Single-Family Houses

According to the Danish Energy Agency, the aspects that affect the energy consumption the most is the condition of the roof, floor, walls, and windows because if the condition of the aforementioned aspects of the house are bad, then there is a big risk of leaks which makes the heat escape and that is bad for both the environment as well as the owner's economy (Parcelhus 1960 - 76, n.d.).

The Danish Energy Agency has made an illustration which illustrates how much heat typically escapes in single-family houses built between 1960 and 1980, the illustration can be seen below:

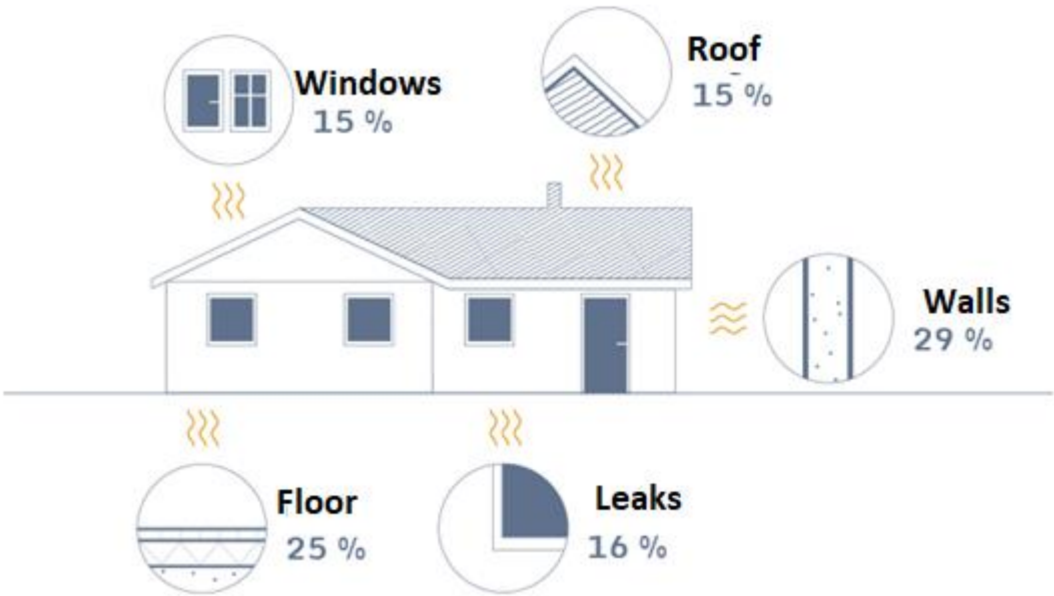



*Illustration of where heat typically escapes on single-family houses built between 1960-1976 (Parcelhus 1960- 76, n.d.).*

The illustration above illustrates that there is potentially a lot of heat loss in single-family houses built between the aforementioned period. Heat loss means that more energy is required to heat up the house, as the heat leaks out of the house due to e.g. bad insulation or leaking windows etc. (Parcelhus 1960 - 76, n.d.). Fortunately, there are ways to minimize the heat loss and it is by optimizing current solutions or by replacing the old solutions with new and more energy-efficient solutions (Parcelhus 1960 - 76, n.d.). As initially mentioned, energy renovation is about reducing energy consumption by optimizing the house itself (Parcelhus 1960 - 76, n.d.). The Danish Energy Agency has made a list of energy improvements that can be done to reduce or eliminate the heat loss significantly, the list is sorted in three parts, the first part deals with roof, walls and windows, the second part deals with the installations in the house and the third part deals with human behavior (Parcelhus 1960 - 76, n.d.).

The following list is the first part of improvements that according to the Danish Energy Agency are recommended to single-family houses from the period between 1960 and 1980 (Parcelhus 1960 - 76, n.d.). Additionally, the list is sorted by which solution energy consults recommends single-family house owners the most (Parcelhus 1960 - 76, n.d.):

1. **Insulation of roof**
    a. Insulation of a roof with unused roof space, so there is at least 300 mm insulation in total. This is easiest to do when the roof needs to be replaced anyway (Parcelhus 1960 - 76, n.d.)
2. **Replacement or renovation of windows**
    a. Replace double-layered windows with three layers of energy-saving windows. Check windows sealing and window joints, if in bad condition change or repair (Parcelhus 1960 - 76, n.d.)
3. **Insulation of exterior walls**
    a. Insulation of exterior walls if possible. Insulation is preferred to be done via the exterior wall. Insulation of exterior walls can be compared giving the house a jacket on (Parcelhus 1960 - 76, n.d.)
4. **Cavity wall insulation**
    a. In 1961 the building regulations required at least 70 mm insulation in the cavity walls, in this case the insulation can be replaced with a more efficient insulation material and if the cavity was is not insulated then it can be a good idea to insulate it (Parcelhus 1960 - 76, n.d.)
5. **Replacement of exterior doors**
    a. If exterior doors are in bad condition it can be a good investment to replace the doors with more energy efficient doors (Parcelhus 1960 - 76, n.d.)

When potential leaks and heat loss in the house are fixed, the next step can be to have a look at the installations around the house, as there can be potential savings by optimizing or by installing a supplementing heat supply (Parcelhus 1960 - 76, n.d.). In this step recommended improvements are also listed by what is more recommended on single-family houses from 1960-1980 (Parcelhus 1960 - 76, n.d.).

Typical improvements on heat supply and heat solution in terms of single-family houses (Parcelhus 1960 - 76, n.d.):

1. **Insulation of heat and hot water pipes**
    a. It is a good investment to insulate heat and hot water pipes if they are not already insulated. Heat loss can be avoided by insulating the pipes with 40-50 mm insulation (Parcelhus 1960 - 76, n.d.).
2. **Installation of a supplemental energy system**
    a. According to the Danish Energy Agency energy consultant typically recommends houses owners to install solar panels on their rooftop (Parcelhus 1960 - 76, n.d.).
3. **Installation of an automatic controller on the heat supply system**
    a. Automatic control of the heating system can control the heat consumption according to the weather. It is most obvious to install an automatic controller if the heat supply system needs to be replaced or renovated (Parcelhus 1960 - 76, n.d.).
4. **Replacement of circulations pumps**
    a. The circulation pump pumps the hot water from the hot water tank to the tap. By installing a circulation pump with thermostat control the user can choose exactly the times of the day when hot water is needed. It both reduces water wastage and lowers the electricity consumption resulting in financial savings (Parcelhus 1960 - 76, n.d.).

5. **Installation of heat pumps**

   a. Heat pumps can be beneficial to install, especially in houses with a heat supply system based on oil. It can also be a good investment in houses with natural gas or houses located in areas without district heating (Parcelhus 1960 - 76, n.d.).

Not everything is about replacement or optimizing the house, a big part of energy savings is about changing human behavior (Parcelhus 1960 - 76, n.d.).

According to the Danish Energy Agency, it is possible to reduce the energy consumption by changing behavior regarding energy consumption (Parcelhus 1960 - 76, n.d.). By turning appliances off when no one is home and by becoming more aware it is possible to save a lot of energy and money (Parcelhus 1960 - 76, n.d.). Another thing that can be done is to buy more energy-efficient appliances and electronic devices (Parcelhus 1960 - 76, n.d.).

### 5.1.3 The Building Regulation and Requirements when Renovating a Single-family House

According to the Danish Energy Agency there are some requirements listed in The Building Regulations which require house owners to re-insulate their house if it is profitable when they are renovating their house (Energikrav bygningsreglementet, n.d.). This means that if a person is renovating their house they are required by regulations to perform energy-saving measures such as re-insulate parts of their house, however, only if it is profitable (Energikrav bygningsreglementet, n.d.). But how does one know if it is profitable or not?

The Building Regulations have provided a formula that helps calculate whether it is profitable to re-insulation or not (Energikrav bygningsreglementet, n.d.). The formula can be seen below:

$$\frac{\text{Yearly Saving in DKK} \times \text{Lifetime in Years}}{\text{Investment}}$$

*Formula to calculate if it is profitable to do energy-saving measures (Energikrav bygningsreglementet, n.d.).*

According to the formula above, the calculation of whether it is profitable or not is defined as: *Savings per year* X (multiplied by) *Lifespan* / (divided by) *Investment.* In relation to investment the investment with re-insulation must be subtracted the investment without re-insulation. The result of that number must be divided the aforementioned (Energikrav bygningsreglementet, n.d.).

If the result is 1.33 or above then it is considered profitable and thus the house owner is required to re-insulate parts of the house (Energikrav bygningsreglementet, n.d.). However, if the result is below 1.33, then it is not considered to be profitable and thus the house owner is not required to re-insulate (Energikrav bygningsreglementet, n.d.). The Danish Energy Agency provides an example of a calculation of insulation:

2.100 DKK/Per Year (Savings per year) X (multiplied by) 40 Years (Lifespan) / (divided by) 245.000DKK (Investment with re-insulation) – (Minus) 190.000DKK (Investment without re-insulation) = 1,52

Or

2.100DKK x 40 Years / 55.000DKK = 1,52

The above example is an illustration of a profitable calculation where the house owner is required to re-insulate (Energikrav bygningsreglementet, n.d.). According to the Danish Energy Agency, if it is not profitable to re-insulate, it can still be a good idea to do so, as one saves the hassle of another renovation in the future (Energikrav bygningsreglementet, n.d.).

The Building Regulation contains requirements that need to be followed when renovating a house (Energikrav bygningsreglementet, n.d.). There are also requirements to heat supply systems which will be listed below:

1. **Gas kettle**

    a. According to the Building Regulations a gas kettle must comply with EU regulations nr. 813/2013, which states that the kettle must have an annual efficiency of at least 86 % (Energikrav bygningsreglementet, n.d.). Additionally, the kettle must be CE-labeled, and only condensing kettle complies with the regulations (Energikrav bygningsreglementet, n.d.).

2. **Oil furnace**

    a. According to the Building Regulations an oil furnace must comply with EU regulations nr. 813/2013, which states that the kettle must have an annual efficiency of at least 86 % (Energikrav bygningsreglementet, n.d.). Furthermore, as per 1. July 2016 it is not allowed to replace an old oil kettle/furnace with a new unit. It is not allowed to install oil kettles in new buildings (Energikrav bygningsreglementet, n.d.).

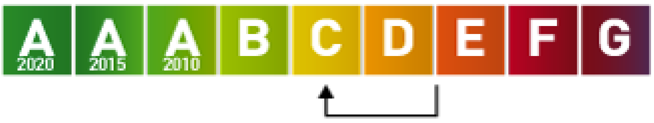
3. **Heat Pumps**

    a. According to the Building Regulations heat pumps must comply with EU regulations nr. 813/2013/EU, which states that the heat pump must be efficient in relation to the building. e.g. 3.0 SCOP (Seasonal Coefficient of Performance) in relation to floor heating (Energikrav bygningsreglementet, n.d.). If the SCOP factor is 3 it means that 1 kWh electricity provides 3 kWh heat (Energikrav bygningsreglementet, n.d.).

### 5.1.4 Energy Labeling of Single-Family Houses

According to the Danish Energy Agency houses are only energy-labeled if they are going for sale or are rented out for more than four weeks, additionally, new buildings are also energy labeled (Parcelhus 1960 - 76, n.d.). But what does the energy label provide?

The energy label provides information about the status of the house seen from an energy-efficiency standpoint (Energimærkning boliger, n.d.). The energy label gives an overall assessment of the condition of the house on a scale from A to G (Energimærkning boliger, n.d.).




*Illustrations of different energy labels (Energimærkninger boliger, n.d.)*

Furthermore, the energy label also makes it possible to receive suggestions on how to energy-improve the house (Energimærkning boliger, n.d.). The energy label is only valid for a period of 10 years, and the scale is based on requirements from the Building Regulations (Energimærkning boliger, n.d.).

Single-family houses built-in 1960-1976 is typically labeled as D or E (Parcelhus 1960 - 76, n.d.).. By doing energy renovation initiatives the energy label can be improved from D or E to C (Parcelhus 1960 - 76, n.d.).

## 5.2 Heat Supply in Denmark

In Denmark, a variety of technologies are used to heat buildings and domestic water ("Information Om Varmeområdet", 2020). According to the Danish Energy Agency, the heat is produced from both fossil fuels and from renewable energy sources, additionally, electricity is increasingly being used for heating purposes ("Information Om Varmeområdet", 2020). If the Danish goal of becoming independent from fossil fuel-based energy sources by 2050, then a continued transition from a fossil fuel-based energy sources to renewable energy sources is required ("Information Om Varmeområdet", 2020).

### 5.2.1 Individual and Collective Heat Supply

In Denmark, the heat supply is divided into two categories, individual heat supply, and collective heat supply ("Information Om Varmeområdet," 2020). According to the Danish Energy Agency, 80 % of all households in Denmark receive heat supply collectively, while the remaining 20 % receive their heat supply individually ("Information Om Varmeområdet", 2020).

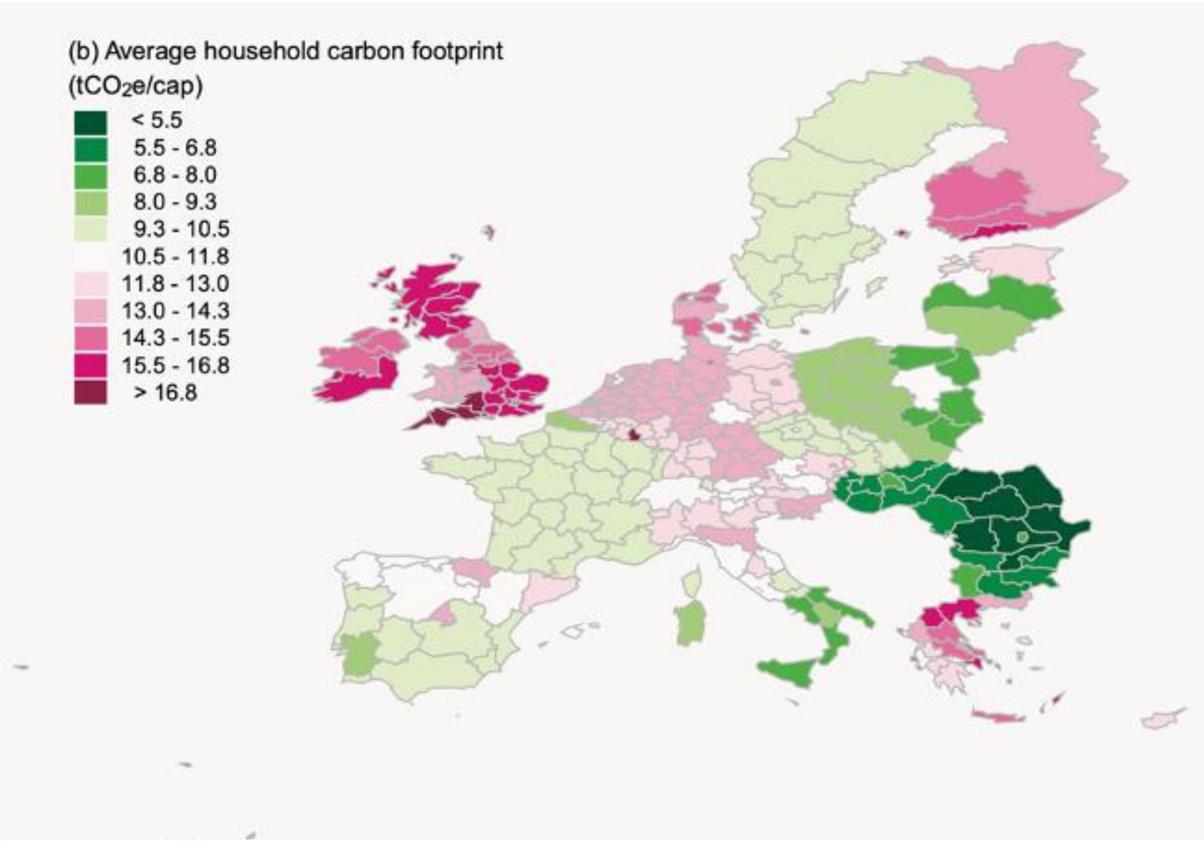
Individual heating is understood as heating where the building is not connected to the collective gas or district heating grid ("Information Om Varmeområdet", 2020). Individual heating is typically done with liquid fuel e.g. oil, heat pumps, or biomass ("Information Om Varmeområdet", 2020). In the past heat supply based on oil was the dominant form of heating, but as the collective heat supply expanded, the individual heating is typically, only common in smaller cities that are distant from bigger cities ("Information Om Varmeområdet", 2020). Today, many house owners are replacing their heating systems based on oil with heat pumps, biomass furnaces, or other alternatives ("Information Om Varmeområdet", 2020).

The collective heat supply system consists of district heating and natural gas ("Information Om Varmeområdet", 2020). In district heating, hot water or steam is transferred from a district heating plant to a household via collective underground district heating pipes ("Information Om Varmeområdet", 2020). Another form of collective heating is natural gas heating where gas is provided to households through a collective underground gas grid ("Information Om Varmeområdet", 2020). Collective heating is typically found in cities and urban areas ("Information Om Varmeområdet", 2020). The collective forms of heat supplies are regulated by the Heat Supply Act ("Information Om Varmeområdet", 2020).

According to the Danish Energy Agency the central key actors in collective heat supply are the municipalities and utility companies ("Information Om Varmeområdet", 2020). Municipalities carry out the heat planning and are responsible for the expansion of the collective heat, however, the expansion must comply with the Heat Supply Act ("Information Om Varmeområdet", 2020). The utility companies have the operational responsibility to provide heat to the consumers ("Information Om Varmeområdet", 2020).

### 5.2.2 Danish Energy Consumption

According to a study about the carbon footprint of the EU households, the average carbon emission from a Danish household in 2017 is about 14,5 tons per year (Ivanova et al. 2017).




*A map of the average carbon footprint of EU households.*

In average, a Danish single-family house from the 1960s and 1970s, that is heated by natural gas, consumes 1630 m³ gas per year (Gregersen, 2019). When combusting natural gas, 2,7 kg of $CO_2$ is emitted for each kg combusted natural gas (Lund 2019). One m³ of natural gas weighs 0,75 kg (Christiansen and Petersen 2020). The total weight of the combusted natural gas in an average Danish household is then 1630 m³ * 0,75 kg = 1223 kg. Thus, the total $CO_2$ emission is 1223 kg * 2,7 = 3303 kg $CO_2$ or 3,3 tons of $CO_2$ emission, which represents about 23% of the total emission of 14,5 tons. Thus, making the energy consumption for heating space and domestic water emission-free will be a gross reduction within the total greenhouse gas emission of a Danish household.

## 5.3 Natural Gas

Natural Gas is a fossil fuel and like other fossil fuels, natural gas forms from organic material, such as plants, animals, and microorganisms, that lived millions of years ago (Turgeon and Morse, 2012).

According to Turgeon and Morse there are several theories that explain how fossil fuels are formed, however, the most common theory is that they are formed underground under intense pressures (Turgeon and Morse, 2012). As organic material, such as plants, animals and microorganisms decompose, they are eventually covered by layers of soil, sediments, and rocks (Turgeon and Morse, 2012). Throughout millions of years, the organic material is compressed and as it moves deeper into the earth it encounters higher and higher temperatures (Turgeon and Morse, 2012). It is the combination of compression and high temperatures that causes the carbon bonds in the organic material to break down and this molecular breakdown produces thermogenic methane which is natural gas that is produced beneath the surface of the Earth (Turgeon and Morse, 2012).

Natural gas mostly consists of Methane (95 %), Ethane (3.8 %) and Propane (0.2 %) (Chemical Composition of Natural Gas, n.d.). However, natural gas also consists of components such as Butane, Nitrogen, Carbon Dioxide, Oxygen, Hydrogen, however, in a smaller quantity than Methane, Ethane and Propane (Chemical Composition of Natural Gas, n.d.).

Natural gas is not only formed in the underground, but it can also be formed by microorganisms called methanogens (Turgeon and Morse, 2012). Methanogens live in the intestines of animals, as well as humans, and in low-oxygen areas near the surface of the earth (Turgeon and Morse, 2012). Methane produced by living organisms is called biogenic methane, and for the most biogenic methane escapes into the atmosphere, however, according to Turgeon and Morse, new technologies are being created to contain and harvest the potential energy of the biogenic methane (Turgeon and Morse, 2012).

As mentioned before thermogenic methane is natural gas that is formed deep beneath the surface of the earth (Turgeon and Morse, 2012). The thermogenic methane can also escape into the atmosphere, as some of the gas is able to rise through porous rocks, which means it eventually disappears into the atmosphere (Turgeon and Morse, 2012). However, most thermogenic methane that rises toward the surface are trapped into sedimentary basins, these sedimentary basins trap huge reservoirs of natural gas, and in order to harvest the natural gas from these reservoirs, a hole must be drilled into the earth down to the reservoirs in order for the natural gas to escape and be harvested (Turgeon and Morse, 2012). Natural gas that is economical to extract is considered conventional gas, however, natural gas that is uneconomical and harder to extract is considered unconventional gas, but according to Turgeon and Morse, new technologies are being invented to make the unconventional gas more accessible and therefore more economical, making the unconventional gas conventional (Turgeon and Morse, 2012).

Natural gas is mostly harvested by drilling vertically down to the reservoir, typically a single vertical hole is limited to the gas reservoirs it encounters (Turgeon and Morse, 2012). In terms of transportation of the harvested natural gas, it is typically done in two ways, either through pipelines or by cooling down the gas to -162 degrees Celsius converting the natural gas into Liquefied Natural Gas (LNG) in order for it to be transported in a liquid form (Turgeon and Morse, 2012).

In terms of consuming natural gas, it is used for industrial, commercial, residential, and transportation purposes (Turgeon and Morse, 2012). In residential homes natural gas is primarily used for heating purposes, e.g. natural gas is used to heat water and to power space heaters, etc. (Turgeon and Morse, 2012). Natural gas when harvested needs to be refined before it can be used in residential purposes. As mentioned before natural gas consists of many elements and components, in order to use natural gas for residential purposes the methane has to be processed and separated from other components, as natural gas used as an energy source in homes is almost pure methane (Turgeon and Morse, 2012). Natural gas is a fossil fuel and emits $CO_2$ when combusted, however, natural gas emits 30 % less $CO_2$ than oil, and 45 % less $CO_2$ than coal (Turgeon and Morse, 2012).

### 5.3.1 Natural Gas in Denmark

The Danish Parliament decided, in May 1979, to establish the Danish natural gas supply system (Marcher, n.d.). The Danish Parliament decided to establish the Danish natural gas supply system in order to make oil a smaller component in the Danish energy supply due to the consequences of the oil crises in 1973 and 1979 (Marcher, n.d.). In relation to the decision of establishing the Danish natural gas system, a Natural Gas Supply Act was made to ensure that the supply of natural gas was organized and implemented in the interests of security of supply, economics and the environment and in order to protect consumers (Marcher, n.d.).

According to Danish Energy Agency the Natural Gas Supply Act regulates transmission, distribution, supply, and storage of natural gas including LNG (Marcher, n.d.). The act also applies to Biogas, and other types of gas so that such gasses technically and safely can be transported through the natural gas system (Marcher, n.d.). In 2004, the act gave the Danish consumers of natural gas the right to choose their own supplier of natural gas (Marcher, n.d.).

In Denmark, the natural gas mostly comes from the North Sea, where it is harvested and then distributed through the transmission system into the distribution network. The distribution network is the connection to the customers (Marcher, n.d.). Energinet owns and operates the transmission system in Denmark (Marcher, n.d.) The transmission system leads natural gas from the North Sea to two Danish storage facilities as well as to Germany and Sweden (Marcher, n.d.). The Danish natural gas system is illustrated in the illustration beneath: The illustration shows the transmission system among the distribution system.

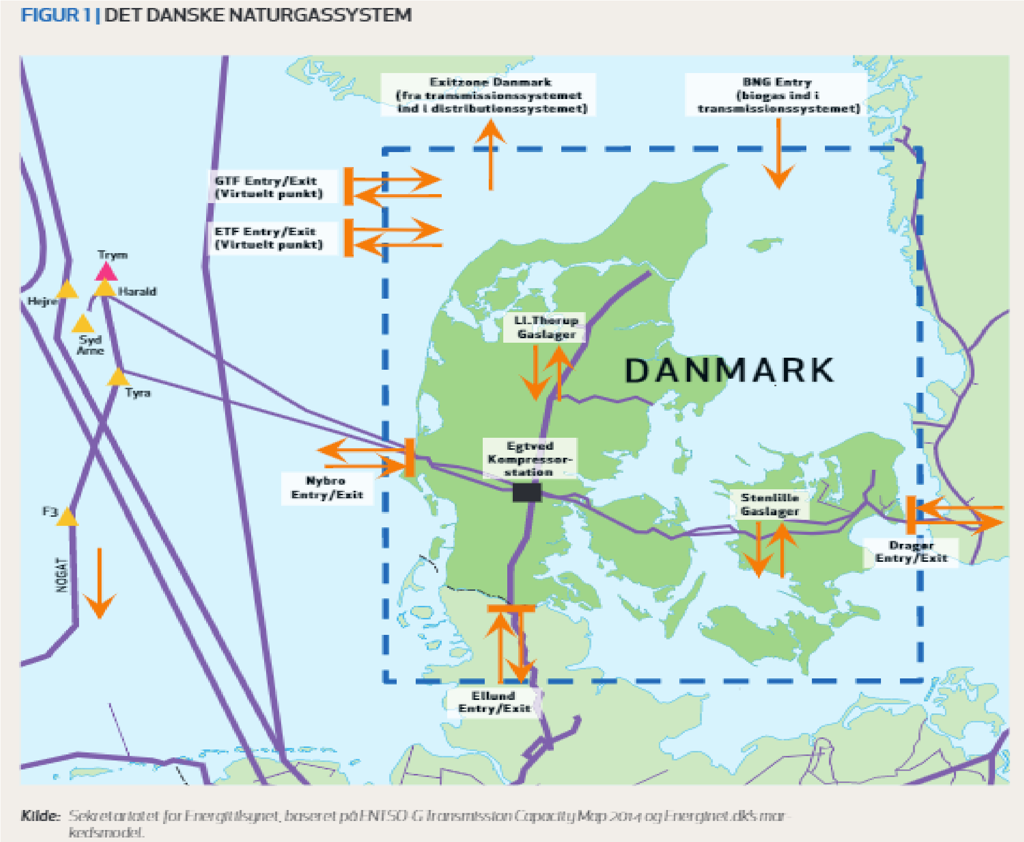



*Illustration of Danish Natural Gas System (Energi Tilsynet, 2015)*

According to the Danish Energy Agency, the distribution system consists of 17,000 Km pipelines and around 400,000 customers, households, energy companies, and businesses that are connected to natural gas (Marcher, n.d.). Before the end-customers receive natural gas, an odorant is added to the gas as a safety mechanism, allowing the customers to smell the gas in case of a leak (Jensen, n.d.).

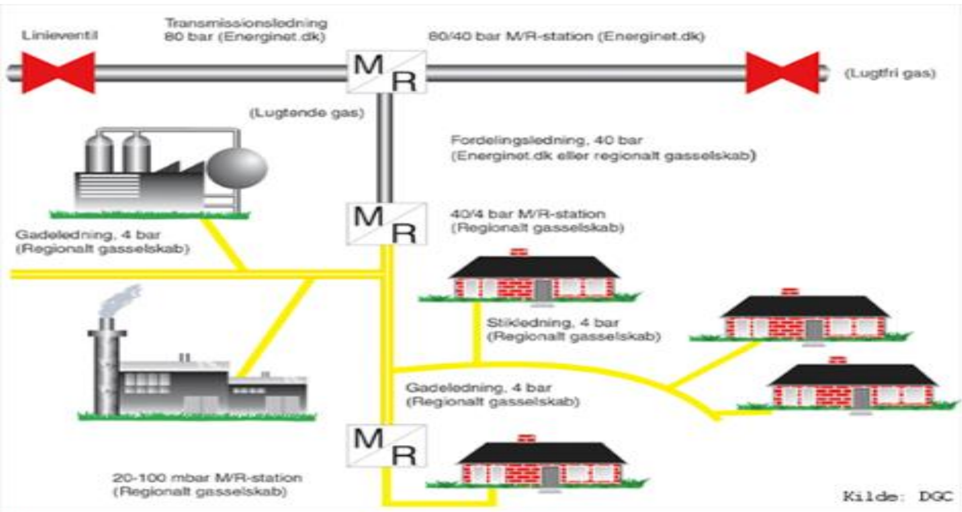



*Illustration of how natural gas is distributed to household (Jensen, n.d.)*

The distribution network was according to the Danish Energy Agency initially designed to receive natural gas from the transmission grid, however, today local biogas plants deliver biogas to the network as well (Marcher, n.d.).

Biogas is a natural type of biofuel that is produced from the decomposition of organic waste. This is done through organic elements that are broken down in an anaerobic environment (Homebiogas, n.d). The organic matter, which could, for instance, be food waste and animal waste releases a blend of gasses which primarily consists of methane and carbon dioxide. The process of biogas starts with the organic waste being placed in a cistern whereupon the organic waste is heated to 38-52 °C. Thereafter, is it pumped towards a reactor, where the biogas is produced. Biogas is primarily used to produce electricity and district heat through a plant gas engine called CHP engine. The produced electricity is sent to the power grid where it is used by households (Bigadan, n.d). Biogas can also be used like natural gas and added to the natural gas grid. Additionally, biogas can also be used as fuel in the transport sector. Underneath is an illustration of a biogas plant where the process is described through significant components in the means of creating biogas (Bigadan, n.d).

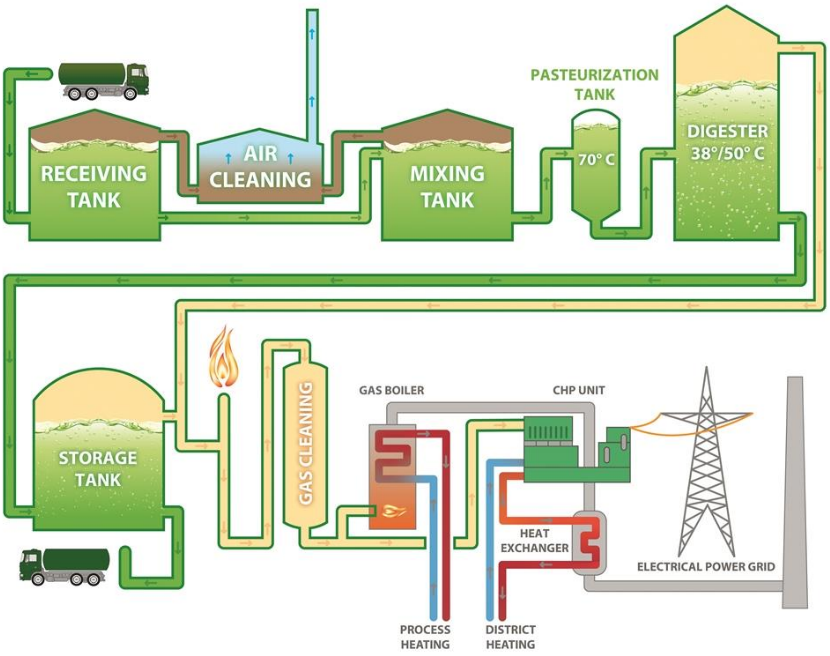



*Illustration from Bigadan of a Biogas production process)*

According to Energistyrelsen, there were around 164 biogas plants in Denmark, where 120 of the biogas plants generate electricity (Energistyrelsen, 2018). A broader look into the 2018 report from Energistyrelsen shows the growth of biogas from 1990 to 2018. In 1990 the production of biogas gave 752 TJ compared to 2018 where the energy production was 13414 TJ, which is an increase of

1684 % in 28 years (Energistyrelsen, 2018). Through the development of applications in biogas, there has been an increase of biogas in the natural gas grid. Approximately 44% of biogas is used in the natural gas grid (Maria Pedersen,2018). The growth in biogas is influenced heavily through political initiatives, here they gave a subsidy from 0.60 DKK /kWh to 0.74 DKK/kWh, additionally, did they agree to give a biogas plants subsidy of 20% and a municipal guarantee on 60% of fixed-asset investment on biogas plants (Torben Kvist, 2011). The political initiatives and the growing application in biogas indicate an increase in biogas plants and biogas as a provider of energy through the natural gas grid.

### 5.3.2 Natural Gas in Danish Households

In Denmark, natural gas is used as a heat supply in some private households that are connected to the natural gas system. The household needs to have a natural gas boiler in order to use natural gas as a heat supply.

A natural gas boiler consists of a furnace where the gas is ignited and a kettle where the water is heated (Bisp and Lindegaard, 2018). The natural gas is lead into the furnace where the natural gas is ignited. In the kettle, the heat from the ignited natural gas heats the water that flows through radiators or underfloor heating, additionally, the heat from the kettle warms the domestic warm water in the household, meaning warm water in the faucets (Bisp and Lindegaard, 2018).

According to Bisp and Lindegaard, if a household already owns a natural gas boiler, that is due to be replaced, it can cost up to 30,000 DKK to replace it with a better and more efficient boiler (Bisp and Lindegaard, 2018). However, it can be expensive if the household initially had another heat supply than one based on natural gas. In order to get a natural gas boiler, gas pipes need to be laid into the house, as the house needs to be connected to the natural gas system (Bisp and Lindegaard, 2018). The typical lifespan of a natural gas boiler for a common household is around 10-30 years. However, due to the technological advancement, a better and more efficient natural gas boiler can be a clever investment as the newer boiler are substantially more efficient. According to Bisp and Lindegaard, a household can reduce their natural gas consumption by up to 25 % by replacing their older natural gas boiler with a newer and more efficient boiler (Bisp and Lindegaard, 2018).

A typical Danish single-family house on 130 $m^2$ from the 1960s/1970s in general uses around 1630 $m^3$ of natural gas per year to heat the house (Gregersen, 2019). There are many different factors that can affect the yearly consumption e.g. if the household uses an old natural gas boiler. Then the consumption would be higher as newer boilers are more efficient (Gregersen, 2019). Additionally, the condition of the house plays a big role as well, because if the house is old then it may not be well isolated, and then it would require more energy to heat up the house (Gregersen, 2019).

According to Gasprisguiden.dk the price for 1 m³ natural gas including taxes, fees, and distribution is about 6.33 DKK per m³ natural gas. The price example is based on a customer in Høje Taastrup Municipality.

As mentioned before, a single-family house on 130 m² built in the 1960s or 1970s uses around 1630 m³ per year to heat up the house, and based on the price provided beneath, this means that it would costs 6,33 DKK * 1630 m³ = 10,317.9 DKK

1 m³ natural gas costs 1,48 DKK without taxes and fees. The distribution of 1 m³ natural gas costs 0,93 DKK without taxes and fees. Fees per m³ is 2,65 DKK, and lastly, taxes per m³ natural gas is 1,26 DKK. A total price per m³ natural gas including taxes, fees, and distribution is 6,33 DKK.

| **Details about fixed price 12 months** | |
|---|---|
| Gas | |
| list price ex. VAT DKK / m³ | 1,40 DKK / m³ |
| Subscription ex VAT DKK / m³ | 0 DKK / m³ |
| Gas total price ex. VAT DKK / m³ | 1,40 DKK / m³ |
| **Distribution** | |
| Distribution tariff duties ex. VAT DKK / m³ | 0.47 DKK / m³ |
| Energy Saving Contribution ex. VAT DKK / m³ | 0.23 DKK / m³ |
| Management fees | 0.04 DKK / m³ |

| | |
|---|---|
| Emergency Tariff duties ex. VAT DKK / $m^3$ | 0.18 DKK / $m^3$ |
| Distribution total ex. VAT DKK / $m^3$ | 0.93 DKK / $m^3$ |
| **Fees** | |
| $CO_2$ Fees | 0.40 DKK / $m^3$ |
| Energy Fees | 2.24 DKK / $m^3$ |
| NOX Fees | 0.0080 DKK / $m^3$ |
| Fees total ex. VAT DKK / $m^3$ | 2.65 DKK / $m^3$ |
| **Total** | |
| Including distribution and fees ex VAT | 5.06 DKK / $m^3$ |
| **VAT** | |
| Total VAT | 1.26 DKK / $m^3$ |
| VAT and Fees total DKK / $m^3$ | 3.92 DKK / $m^3$ |
| **Total** | |
| Including distribution, fees, and VAT | 6.33 DKK / $m^3$ |

Example of Natural Gas Price Pr $M^3$ including taxes and fees. Price example 12 months fixed price. Example takes example in prices for customers in Høje Taastrup Municipality (gasprisguiden.dk)

## 5.4 District Heating

District heating is described as warm water from power plants, that flows through an underground pipe system and provides households with warm water, via a forward pipeline, to heat radiators, floor heating, and provides heat to the domestic water that is used in faucets. When the warm water has been "used" by the consumer it is returned to the power plant, via a return pipeline, where it is heated up again (Frederiksen and Lindegaard, 2019). The water in the district heating system is in a closed system, which means that it cannot be consumed as such, the water from the district heating is used to heat the water system in the house (Frederiksen and Lindegaard, 2019).

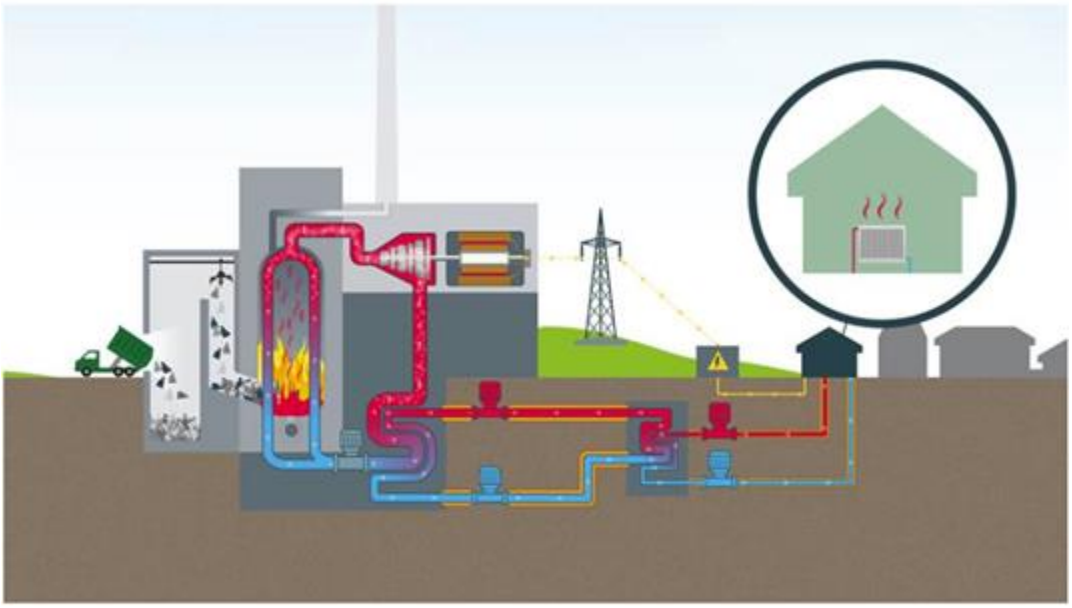


*Illustration of how the district heating system work. (Vestforbrændningen.dk)*

A power plant can reduce its consumption of fuel with 30 % if it produces both electricity and heat simultaneously (Frederiksen and Lindegaard, 2019). Approximately 66 % of the district heating in Denmark is produced on a power plant that produces both electricity and heat (Frederiksen and Lindegaard, 2019). According to the Danish Energy Agency in 2018 the district heating was obtained by burning 54,9 % biofuel (straw, wood, biodegradable waste), 9,2% waste (non-biodegradable), 29 % fossil fuel (Coal, oil, natural gas) (Frederiksen and Lindegaard, 2019). Additionally, in 2018 the district heating was obtained by 2,5 % solar and geothermal energy, 2,8 % biofuel and biogas, and 1,6 % electricity and heat pumps (Frederiksen and Lindegaard, 2019).

According to Frederiksen and Lindegaard, the water in district heating is heated with surplus heat from different processes such as the production of electricity from power plants, incineration of waste on power plants, surplus heat from industry, solar power, heat pumps, and surplus heat from data-centrals (Frederiksen and Lindegaard, 2019).

As mentioned earlier the warm water travels through the underground district heating pipe system. There are two main pipes, one forward pipeline which transports the warm water to the consumers, and one return pipeline that returns the “used” cold water to the power plant (Frederiksen and Lindegaard, 2019). When the warm water reaches a household, it is usually 70-80 degrees. The temperature of the water when it reaches the household varies and is affected by the seasons, etc. (Frederiksen and Lindegaard, 2019).

District heating is considered an environment-friendly and energy-efficient heating supply due to the simultaneous production of heat and electricity, as a result of the simultaneous production the power plant can reduce its consumption significantly (Danfoss, n.d.). According to Danfoss, the district heating plants are better at reducing emissions compared to individual heating systems due to the heating plants having more advanced pollution control equipment (Danfoss, n.d.).

District heating is compatible with renewable energy sources which makes district heating an environmentally friendly and sustainable form of heat supply (Danfoss, n.d.).

### 5.4.1 District Heating in Denmark

According to the Danish Energy Agency, Denmark is one of the most energy-efficient countries in the world due to the extensive use of district heating (Danish Experiences on District Heating, n.d.). Over the past decades, the energy efficiency has increased, while the carbon emissions have decreased in Denmark (Danish Experiences on District Heating, n.d.).

In Denmark, around 64 % of all private households are connected to district heating as the main heat supply for space heating and domestic water heating (Danish Experiences on District Heating, n.d.). According to the Danish Energy Agency, Denmark has six large central district heating areas, that distribute to the heat production of 67 petajoules per year. These six areas are located around major cities in Denmark (Danish Experiences on District Heating, n.d.). Additionally, 400 smaller regionalized district heating areas with a heat production of 53 petajoules are spread around Denmark (Danish Experiences on District Heating, n.d.).

In Denmark, the first combined heat and power plant was built in 1903, which served as a waste burning plant, the plant made is possible to deal with waste while also providing electricity and heat in the form of steam to a hospital (Danish Experiences on District Heating, n.d.). In the 1920s and 1930s, district heating system was developed based on surplus heat from electricity production, the district heating supplied urban areas with heat and at that time district heating accounted for 4 % of the Danish heat supply (Danish Experiences on District Heating, n.d.). According to The Danish Energy Agency, district heating started to expand, however, especially after the oil crises in the 1970s, district heating expanded quickly (Danish Experiences on District Heating, n.d.).

At the oil crisis in 1973-1974, the energy consumption per capita had risen to a very high level, which meant that an urgent need to save energy was essential in order to reduce Denmark´s consumption and also reduce Denmark´s dependency on imported fuels as well as reduce the price on heating solutions for the customer (Danish Experiences on District Heating, n.d.). As a result of the oil crisis, Denmark decided to expand the combined heat and power system from larger cities to medium and smaller cities, which meant that in the late 1970s around 30 % of all homes in larger cities were supplied by the district heating. (Danish Experiences on District Heating, n.d.). According to the Danish Energy Agency, the production of district heating in 2014 was around 121,5 petajoules, with almost 50 % of the production based on renewable energy sources (Danish Experiences on District Heating, n.d.). In Denmark, there are buried more than 60,000 kilometers of district heating pipes across the country.

District heating in Denmark is delivered in two ways: direct district heating or as indirect district heating (Frederiksen and Lindegaard, 2019).

In direct district heating, the hot water from the district heating pipes runs directly into the radiator pipes in the household (Frederiksen and Lindegaard, 2019). The water typically circulates in two ways: either the water is circulated by the power plant, or by a circulation pump in the household (Frederiksen and Lindegaard, 2019). Around 60 % of the district heating in Denmark is delivered as direct district heating. This applies to cities such as Aalborg, Aarhus, Odense, and Esbjerg (Frederiksen and Lindegaard, 2019).

In indirect heating, the hot water from the power plants heats up the water running in the building's pipe system through a heat exchanger (Frederiksen and Lindegaard, 2019). The, now warm, water in the building's pipelines circulates around the pipe system via a circulation pump that pumps the water around the pipe system into the radiators or floor heating (Frederiksen and Lindegaard, 2019). The district heating water is in a closed system, and when it has delivered its heat to the radiators and the hot water tank, it is sent back to the district heating plant via the return pipeline (Frederiksen and Lindegaard, 2019).

Approximately 40 % of district heating in Denmark is delivered as indirectly district heating. This applies to cities such as Copenhagen, Frederiksberg, Randers, Roskilde, etc. (Frederiksen and Lindegaard, 2019).

In terms of the economic aspects of district heating, it is considered a cheaper heat source than gas, oil, and electricity, however, the price of district heating is subject to how close the buildings are to each other and the price of the fuel that the district heat plant uses to heat the district heating water (Frederiksen and Lindegaard, 2019). According to Frederiksen and Lindegaard, the price varies from heat plant to heat plant, and the most expensive price is 4,5 times more than the cheapest price (Frederiksen and Lindegaard, 2019).

### 5.4.2 District Heating in Høje Taastrup Municipality

Høje Taastrup Fjernvarme a.m.b.a (HTF) is the district heating distributor in Høje Taasstrup Municipality (Høje Taastrup Fjernvarme, n.d.). HTF covers the area of Høje Taastrup Municipality. The map beneath illustrates the district heating pipe system in Høje Taastrup Municipality that are controlled by HTF (Høje Taastrup Fjernvarme, n.d.). The purple pipeline is the forward line that provides households with warm water and the blue return line returns the "used" cold water back to the heating plant, for the water to be reheated (Høje Taastrup Fjernvarme, n.d.).


*Map of the district heating system in Høje Taastrup Municipality. Purple line= Main forward pipeline. Blue line= main return pipeline (HøjeTaastrupFjernvarme.dk)*

According to Gregersen, a single-family house on 130 m² from 1960s/1970s uses around 18,100 kWh district heating to heat the house per year (Gregersen, 2019). Based on this information we can calculate the price of district heating by basing the price on HTF´s 2020 price rates (Høje Taastrup Fjernvarme, n.d.).

According to HTF a household under 500 m² must pay 1.194,76 DKK including VAT per year for the subscription of the district heating meter (Høje Taastrup Fjernvarme, n.d.). Additionally, a household under 500 m² must pay a power charge on 25,45 DKK including VAT per m² per year. Furthermore, a household under 500 m² must pay a variable charge of 585,09 DKK including VAT per MWh used (Høje Taastrup Fjernvarme, n.d.).

| **Tariff Rates 2020**<br>**User Fees**<br>**Area < 500 m²** | **Price ex. VAT** | **Price inc. VAT** |
|---|---|---|

| | | |
|---|---|---|
| Subscription meter DKK per Year | 955,80 DKK | 1.195,76 DKK |
| Energy Fees DKK per m² per Year | 20,36 DKK | 25,45 DKK |
| Variabel Fees DKK per MWh | 468,07 DKK | 585,09 DKK |

Based on Gregersen´s example regarding the single-family house from the 1960/70s which uses around 18,100 kWh per year to heat up the household, it would cost 585,09 DKK * 18,1 MWh = 10.590,1 DKK including VAT, excluding effect charge and subscription charge (Høje Taastrup Fjernvarme, n.d.).

In terms of establishment of the connection to district heating of a single-family house, the price rate in Høje Taastrup Municipality is a onetime fee of 43.495,97 DKK including VAT + an investment contribution of 75,09 DKK including VAT per m² (Høje Taastrup Fjernvarme, n.d.).

| **Connection Charge**<br><br>**Area < 500 m²** | **Price ex. VAT** | **Price inc. VAT** |
|---|---|---|
| Socket wiring contribution fees DKK | 34.769,78 DKK | 43.495,97 DKK |
| Investment contribution fees DKK per m² | 60,07 DKK | 75,09 DKK |

Furthermore, there is a leak monitoring fees on 200 DKK including VAT per year and Service of the district heating system fees on 671,88 DKK including VAT per year on a residential district heating unit (Høje Taastrup Fjernvarme, n.d.).

## 5.5 Oil-fired Boiler

An oil-fired boiler is a circulation system, that heats a residence by using the heat from the combustion of oil to heat up water which is then distributed by pipes to radiators throughout the residence. After the water on its journey through the pipes and the radiators have submitted heat to the residence, and have decreased in temperature, it returns to the boiler to get reheated (Smith, 2020). There are two types of oil-fired boilers. The conventional and the more modern condensing oil-fired boiler. The conventional type alone uses the heat from the combustion of the oil. This means, that the conventional boiler has a yield of not much more than 75%. The condensing type, on the other hand, uses not only the heat from the combustion, but also exploits the heat from the smoke derived from the combustion. This contributes to a yield of up to 95% ("Forskellen På Kondenserende Og Konventionel Oliekedel" 2020).

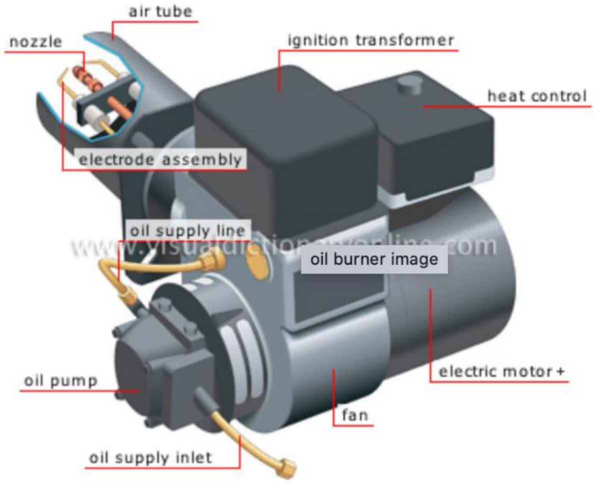
An oil-fired boiler consists of four parts. A tank to contain the oil, a burner to combust the oil, a pot to heat water, and a chimney to lead out excess heat and smoke.

### 5.5.1 The Tank

Unlike the gas-fired boiler, the oil-fired boiler does not get its fuel from an external source but from a tank located on the property. This means that when owning an oil-fired burner, one must fill up the tank whenever needed. Oil tanks come in different shapes and sizes, but often they can contain oil for a substantial amount of time. Many households only fill the tank once or twice a year, depending on the consumption and the size of the tank.


### 5.5.2 The Burner

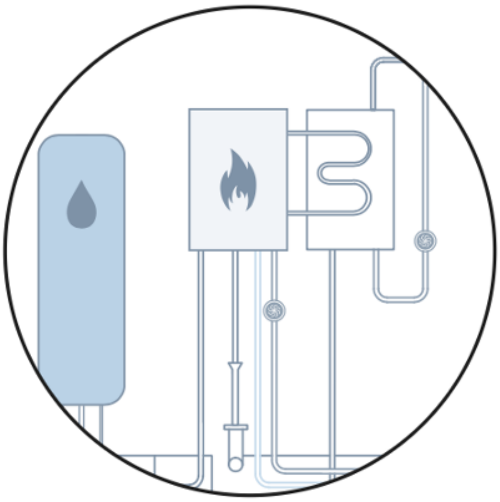
From the tank, the oil is pumped with high pressure through a nozzle into the burner, where the oil is ignited. This creates an intense flame, which is led into the pot ("House:: Heating :: Forced Hot-Water System :: Oil Burner Image - Visual Dictionary Online" 2020).




### 5.5.3 The Pot

In the pot, the intense flame enters a chamber where it heats up the air inside. In the pot, the water that circulates in the system runs through some pipes, thus the water is heated and ready to be sent through the pipes and radiators to heat up the residence before going back into the pot to be reheated ("Sådan Fungerer Et Oliefyr - Kedel, Brænder, Forvarmer Osv. - HEED" 2020).

Additionally, the boiler also heats water for household purposes, e.g. hot water in the faucets (Lindegaard, Blomsterberg and Frederiksen 2020).



### 5.5.4 The Chimney

Like in any other combustion, the burning of oil produces not only heat but also excess gases e.g. carbon dioxide which needs to be led out of the system (Williams 1990). When the combustion is completed in the pot, all excess gases are led out of the system into the air outside by the chimney.

The costs of purchasing an oil-fired boiler and its separate parts, as well as the costs of servicing, depends on the type of boiler. Since the condensing type is the most common in 2020, this is the type that will be used to exemplify in the following.

How much oil a household consumes in a year depends on several factors. e.g. the size of the house, how well the house is isolated, the preferred temperature, or the amount of hot water usage. This is probably why the information on average energy consumption for heating a household varies from one source to another, going from 1650 to 2350 liters of oil per year ("Hvor Meget Fyringsolie? Beregn Dit Forbrug, Og Find Billig Fyringsolie" 2020; Gregersen 2020; "Boligens Energi" 2020). Considering a yield of 95%, the baseline of oil consumption within a household is set to 2000 liters per year. In the writing, the lowest price on domestic fuel oil is 6469 DKK for 1000 liters of oil ("Fyringsolie - Prissammenligning, Find Billigste Fyringsolie Pris" 2020). Considering a consumption of 2000 liters of oil per year, the total annual cost of domestic fuel oil, in this example, is 12938 DKK. It must be noted that the current oil price is extremely low and a result of the ongoing Covid-19 pandemic (Plechinger and Heering 2020).

In Denmark, it has been prohibited since 2013 to install oil-fired boilers in newly built houses and since July 2016 to replace an old oil-fired boiler with a new model, if it is possible to install either district heating or natural gas heating in the area ("Begrænsning Af Oliefyr I Danmark - Sådan Er Reglerne" 2020). Maintenance or service of the oil-fired boiler is not required by law, but professionals recommend that the boiler is serviced once a year. This ensures that the boiler will run smoothly as well as combusting the oil as efficiently as possible, thus using less oil. The price for an annual service check is 2.400 DKK. This price includes the possibility of calling a technician if a problem with the boiler occurs (Oliefyrsservice - Udnyt Din Fyringsolie | LYGAS Energiteknik - LYGAS Energiteknik A/S" 2020). Since it is prohibited to install new oil-fired boilers or to replace old ones, and since the field of study in this thesis deals with a local area where it is possible to install either district heating or natural gas, the economy regarding the installation of a new boiler, will not be further investigated in this study. However, the oil tank may still be replaced. In fact, in some cases, the owner is obliged to replace the tank. Depending on different factors like age, material, if it has inside corrosion protection, or if it is under or above ground, the oil tank has an expiring date on which it, at the latest, has to be replaced (Jensen, Pasternak and Sode 2020).

A new oil tank can be purchased in the price range of 8000-10000 DKK ("Olietanke - Køb Din Olietank Her Og Spar Både Tid Og Penge" 2020). In this example, an above-ground tank with inside corrosion protection will be used. Such a tank will have to be replaced after 40 years.

Domestic fuel oil has a $CO_2$-emission factor of 2,7 tons per 1000 liters of oil ("Hvordan Vejer Man $CO_2$-Udledningen?" 2020). This means, that a household in this example emits 5,4 tons of $CO_2$ per year.

## 5.6 Electricity

In this section, we aim to describe electricity as a heat supply in single-family houses. How it functions as a heat supplier, and how effective it is compared to other heat sources. Lastly, we aim to describe how electricity can be stored in relation to the overproduction of electricity. Additionally, in this section we intend to inspect the correlation electric heating has with carbon dioxide.

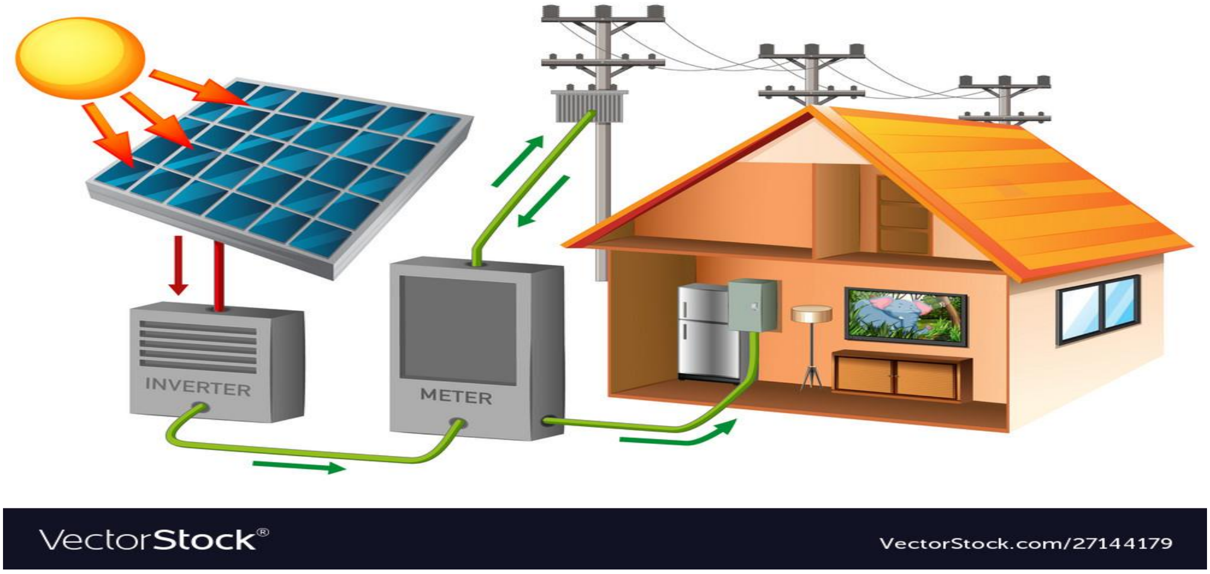
Electric heating describes the process where electrical energy is converted to heat energy. The process of electric heating is often used in an electric heater (Kubba, 2016). An electric heater is a device that changes electricity to heating through electric resistors inside the device. Most electric heaters use nichrome wires which transform electric energy into heating energy (Kubba, 2016). The process of turning electric energy into heating energy is different from electric heaters to heat pumps. A Heat pump uses an electric motor to operate a refrigeration cycle that uses heat from an outside source which could be the air or ground into a specific area so it can be warmed (Sam Kubba, 2016). Heat pumps will be further described later in this chapter.

### 5.6.1 Electric radiator

Electric radiators are one of the most simple ways to warm a house because it just needs a wall socket to work. There are two kinds of electric radiators. The most common is the one which has threads of steels which the current is going through and that results in heat (Fredriksen et al. 2016). This kind of electric radiator works similarly to a toaster, where you can see the threads getting red and hot, but instead it is hidden in an electric radiator. The second one is an electric radiator which works without threads. When the power comes from the wall socket it will warm the oil in the radiator up and then warm the room up. This process is a little bit longer than the first electric radiator, but the energy consumption is approximately the same (Fredriksen et al. 2016). It cost around twice as much to warm a house with electric radiators than natural gas or district heating whereas electric radiator is easier to install compared to natural gas or district heating (Fredriksen et al. 2016). The maintenance of an electric radiator is quite simple and just needs to be wiped clean sometimes (Fredriksen et al. 2016). The longevity of an electric radiator is approximately 30 years (Fredriksen et al. 2016).

### 5.6.2 Solar Panel

Solar cells are used to produce electricity from sunlight. Solar cells are activated through the light from the sun and not from the sunray, this means the warmth from the sun. Therefore, solar cells can still produce power even if it is cloudy (Klimaenergi solcelleanlæg, 2020). Solar cells produce direct current and are in correlation with the size of the solar cell panel and the intensity of the sun. The solar cell panel is built upon the chemical element silicium which is a semiconductor. (Klimaenergi solcelleanlæg, 2020). The power from solar cell panels is direct current and needs to be converted to alternating current so it can be used in houses. Direct current gets converted through a net-inverter which is placed near the electricity meter in the house, hence convert electricityricity to the house. The price of a solar cell panel is dependent on two things which are size and quality. A danish household needs approximately 4 kWp solar panels for its electrical consumption which will cost between 35.000-56.000 DKK (Klimaenergi solcelleanlæg, 2020). The energy which is not used in the household will be handed away to the grid (Klimaenergi solcelleanlæg, 2020). If it is not used in the first hour of production, then it would be given away for free to the grid. (Klimaenergi solcelleanlæg, 2020).




*An illustration of a solar cell as energy supply in single-family house*

The customer of a solar cell panel can buy a battery that can store the excess production of energy. There is still a lot of new inquiries on the market of batteries to solar cell systems and the current devices are very expensive. Therefore, electricity should be used in the moment and hence create a balance between production and demand for the security of supply (Pernille Skovmose, et.al, 2010)

The table underneath describes different batteries to store the excess energy that the solar cell panel has created.

| Category | How it works |
| --- | --- |
| Batteries | Batteries can convert chemical energy to electrical energy. There is a lot of different electrical instruments which could be charged. This could, for instance, be a battery in an electrical vehicle, and therefore could batteries similar to electric vehicles be used to store excess energy<br><br>(Energilagring-Fremtidensenergi,2020) |

| | |
|---|---|
| | |
| SMES | This process describes when direct current runs through a superconducting spool, which accumulates and store the energy in the magnetic field of the spool (Energilagring-Fremtidensenergi,2020). |

### 5.6.3 Solar Thermal Collector

There are two different solar thermal collectors. One can provide hot water and contribute to the heating of the home, whereas the second solar thermal collector just heats the water.

A solar Collector uses the energy of the sun to create hot water. This is done by heating the water in a hot-water tank through a central heating pump (Enrgi,2020). The fluid releases the heat and then turns back to the solar thermal collector and therefore it can create a circular heating system where it preheats and then releases the heat to the hot-water tank (Enrgi, 2020). Beneath is an illustration of how a solar thermal collector works

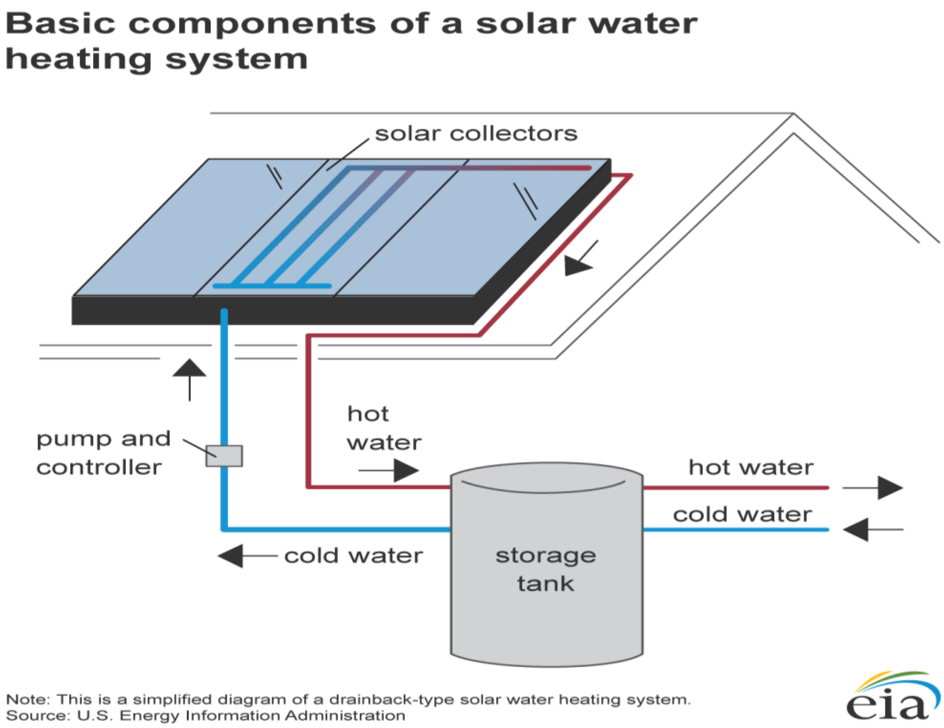



*Illustration from EIA of the basic components of solar thermal collector*

### 5.6.4 Electricity and Carbon Dioxide Emission

The correlation between $CO_2$- emission and electricity, has in 2019 been at its lowest so far (Energinet, 2020). In the last ten years, the $CO_2$- emission from electricity has lowered by nearly 70 percent from 2010. This indicates that there has been a major change in technologies and the effectivity of technologies within electricity consumption. According to Dansk Energi the goal of $CO_2$ reduction in 2050 could be attained if the development continues (Jensen and Hasforth, 2017). In 2019 the $CO_2$ emission was 150 g. pr. kWh, which is significantly lower than in 2018, where it was 199-gram per kWh (Energinet, 2020). Underneath is a diagram of the gram per kWh in the last 10 years in Denmark.

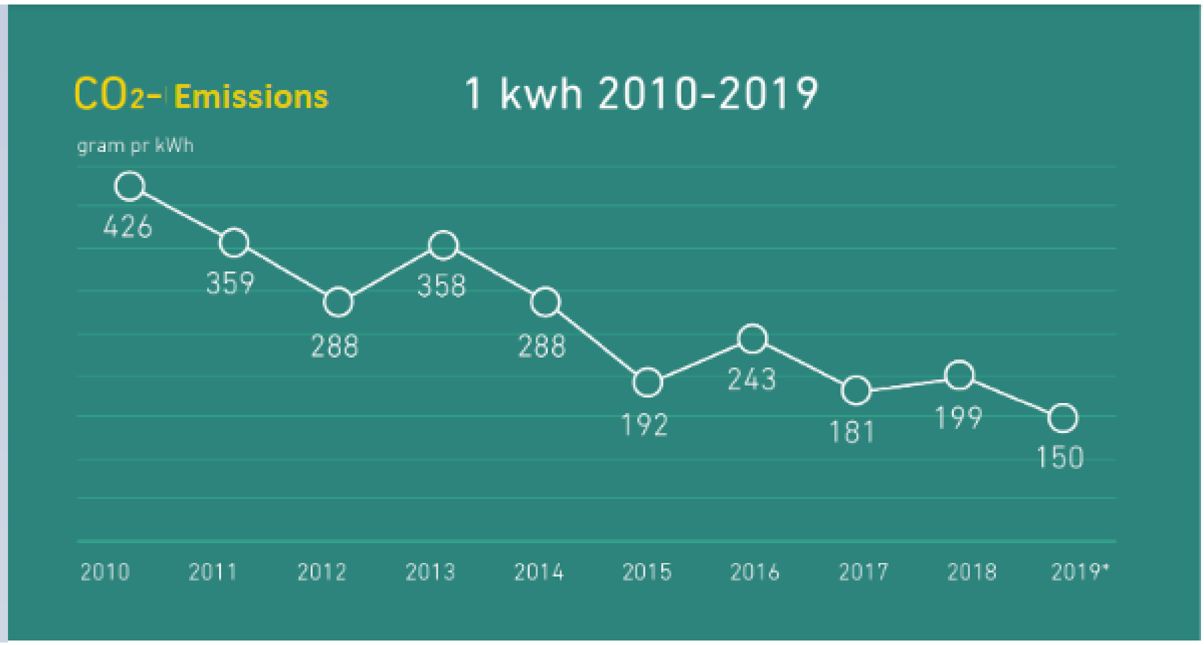



*Diagram of $Co_2$ – emissions by 1 kWh from 2010-2019*

This diagram from Energinet shows the development of $CO_2$- emission which has decreased significantly in the last ten years with 426 g pr kWh in 2010 to 150 g per kWh in 2019. It is assumed that 2050 will be $CO_2$- neutral (Jensen and Hasforth, 2017).

### 5.6.5 Windmill

In this section, we aim to describe the influence of windmills as an energy source and how much energy windmills provide for the Danish energy grid.

In 2017 43,4 % of the Danish energy consumption was provided by windmills, which is a new Danish and world record. The Danish energy system was elected to the best energy system in the world three times in a row (Refsgaard Jensen 2018). Since 1970 there has been a major progression in windmills in Denmark and with the technological development and the capacity of the windmills, it has influenced nearly 50 % of the energy consumption in Denmark ("Fakta Om Vindenergi" 2020). Danish companies are leading in the development of windmills and the export of windmills has a significant influence on the Danish economy. It is mainly municipalities that are responsible for planning the installation of windmills in their area, however, private persons can also invest in windmills on their private plot ("Fakta Om Vindenergi" 2020). In 2018 there was a new energy agreement with enhancements on the term for installations of windmills.

According to Wind Europe's report in 2018 windmills are on the edge to overtake natural gas as the main energy source in Europe. Furthermore, the report assumes that wind and sun energy will surpass fossil fuel in the upcoming years ("Vindmøller - Den Store Guide" 2020). The production of energy from windmills is sent into the supply network. Through cables and masts, it provides energy for power sockets in Danish households. There must be a correlation between electricity production and energy consumption from an economical perspective for energy prices. ("Vindmøller - Den Store Guide" 2020).

## 5.7 Heat Pumps

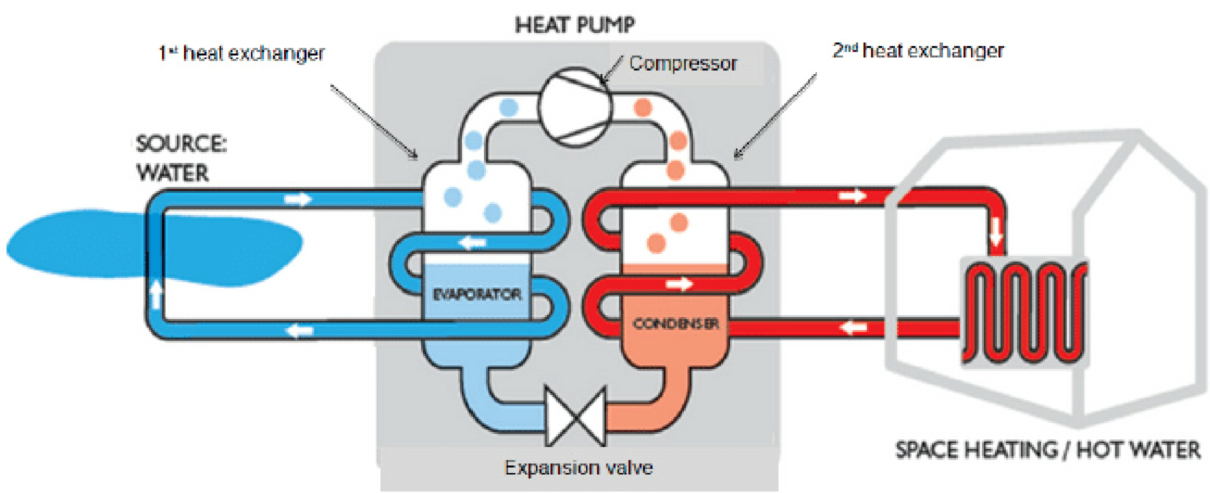
When dealing with heats pumps as domestic heating systems, there are typically three different types of systems:

1. **Geothermal Energy**
2. **Air to Water Heat Pump**
3. **Air to Air Heat Pump**

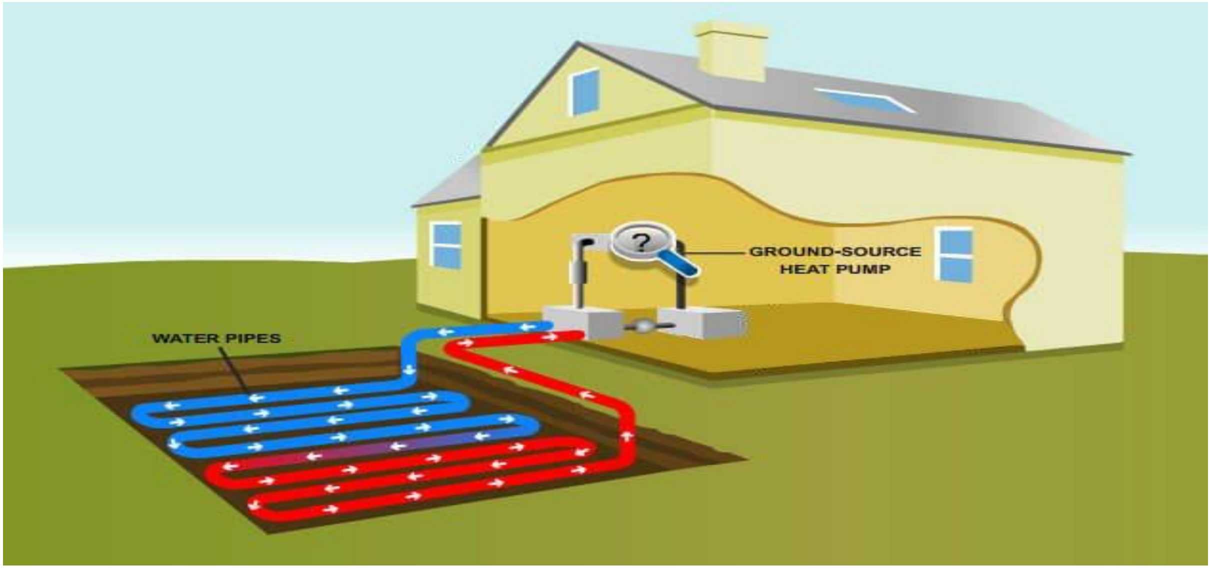
Each of these types has its pros and cons, thus there is no universal solution and factors like the buyer's heat consumption, needs, and current energy supply must be considered ("Varmepumpetyper" 2020)

### 5.7.1 Geothermal Energy

Geothermal energy is a technology that utilizes the energy within the ground provided by the sun. It is a heat pump, that converts the energy from the ground into heat energy. The heat pump is connected to a radiator system. To extract the energy from the ground, a liquid is led through pipes that are submitted into the ground. Here the liquid gets heated before running back to the heat pump. The heat pump then extracts the energy from the liquid and transfer it to the water that runs in the radiator pipe system, thus sending heat around the house. Then the water runs back to get reheated. The heat pump runs on electricity and for every kW electricity consumed, the heat pump provides up to four to five kW heat energy. The geothermal energy heat pumps also heat domestic water (Sode and Jensen 2020).



There are typically two different ways to install the pipe system in the ground. The horizontal and the vertical. The horizontal way is to submit the pipe system, as the name suggests, horizontally throughout the ground and quite shallow, typically around one meter, so that the system can utilize the energy when the sun heats the ground. The area needed for this depends on e.g. the size of the house and the quality of the soil in the ground. A moister soil leads the energy better than a drier soil. Usually, three to four square meters of pipe system is needed per one square meter living space that needs to be heated. When installing this system, it has to be considered, that planting a tree or building a shed above it, will reduce its effectiveness, since the soil will not be heated as well, as when it is directly exposed to the sun (Ibid.).




The vertical installation does not need the same area as the horizontal installation, since the pipe system is submitted vertically into the ground. Here the pipes will usually be submitted 160 meters into the ground. At this depth, there is no energy provided from the sun, so here the energy comes from within the ground (Ibid.). Thus, the vertical installation needs a much smaller area, but the cost of installation is significantly higher. On a more positive notion, the vertical installation is more efficient and will leave the owner with lower operating costs ("Hvad Er Lodret Jordvarme? (2020) | Jordvarmeanlaegpris.Dk" 2020).

To be suited for a geothermal energy system, the residence needs to be properly isolated. If not, it can be difficult to generate a sufficient amount of heat. Also, it needs to be considered, that the temperature in the water running to the radiators – the flow temperature -are lower than with other heat supply systems, so it may be needed to replace the current radiators or add extra ones, to provide a sufficient amount of heat (Sode and Jensen 2020).

The costs of installing a geothermal energy system vary a lot and are dependent on different factors. It can be expected that a horizontal system for a regular Danish residence on 130 square meters will cost around 100.000-130.000 DKK (Sode and Jensen 2020), while the costs of a vertical system can be expected in the range of 200.000-250.000 DKK ("Hvad Er Lodret Jordvarme? (2020) | Jordvarmeanlaegpris.Dk" 2020).

The annual costs of running the geothermal heat pumps depend on the consumption and the SCOP of the heat pump. SCOP is the abbreviation of ‘seasonal coefficient of performance’. The SCOP of the geothermal energy heat pumps varies. At a Danish supplier, the SCOP of their models goes from 4,8 to 5,59 ("Jordvarmepumper - Få Hjælp Til At Vælge Din Jordvarmepumpe Lige Her" 2020). To exemplify, this study will set a SCOP of 5. This means, that for every kW put into the pump the output will be 5 kW.

If an average Danish household’s annual heat energy consumption is 20.000 kWh it will need to provide 4.000 kWh electrical energy to the heat pump.

In the writing, the cost of electricity with a fixed price at a Danish supplier is 2,19 DKK not including the subscription fee of 39 DKK per month ("Køb El" 2020).

It is not required by law to conduct a service check on the geothermal energy heat pumps, but it is recommended by professionals. An annual service check at a Danish plumbing company in the writing costs 2.295 DKK ("Service Udført Efter Producentens Anvisninger" 2020).

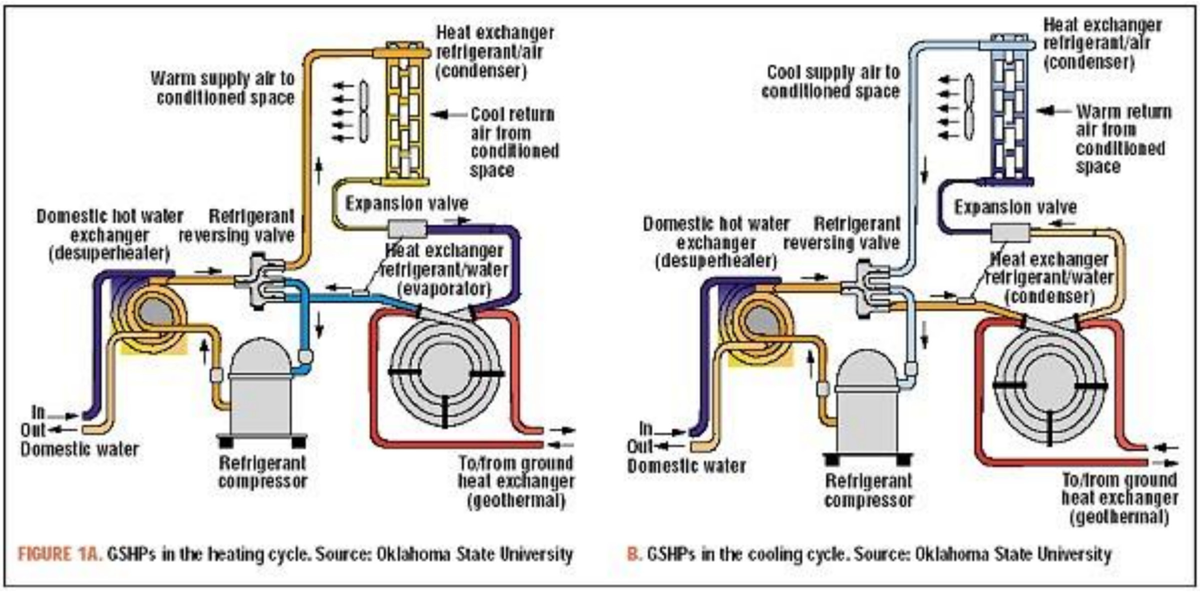
The carbon emission from electricity varies over time, depending on how much wind there is in the given timeframe. In 2019, the carbon emission from an average kWh from the Danish power grid was 150 grams (Wittrup 2020). Thus, the annual carbon emission from the example above will be 150 grams $CO_2$ x 4.000 kWh = 600.000 grams or 0,6 tons $CO_2$ emission

### 5.7.2 Air to Water Heat Pump

Like the geothermal energy heat pump, the air to water heat pump is connected to the radiator pipe system or floor heating. Like in the case of geothermal energy, the flow temperature in the system is lower than the flow temperature in a gas- or oil boiler system, thus the radiators may need bigger dimensions or more radiators need to be added and the residence needs to be properly isolated. Like the geothermal energy heat pump, the air to water heat pump produces energy for both space heating and domestic water heating (Sode et al. 2020).

The air to water heat pump utilizes the energy from the outside air to produce energy for heating the inside air and water. To do this, the system is divided into two units. One unit on the outside of the house and another unit on the inside. The outside unit consists of a ventilator, that sucks in the air and directs it to a heat exchanger that transfers the heat from the air to a refrigerant. A compressor then increases the pressure, thus raising the temperature in the refrigerant. The refrigerant is now led into the inside unit of the heat pump, where the refrigerant heats up the water and sends it through the radiator pipe system before it returns to be reheated (Ibid.).

The air to water heat pump runs on electricity and delivers around 3 times the energy that it consumes. At times with extreme cold, below -10 degrees Celsius, or at times where hot water is used simultaneously throughout the house, the heat pump can have difficulties maintaining the temperature, which is why the hot water container in this system typically has an electrical cartridge mounted (Ibid.).




*The costs of an air to water heat pump including installation is in the range of 80.000 to 100.000 DKK for an 80-140 square meter residence (Nielsen 2020).*

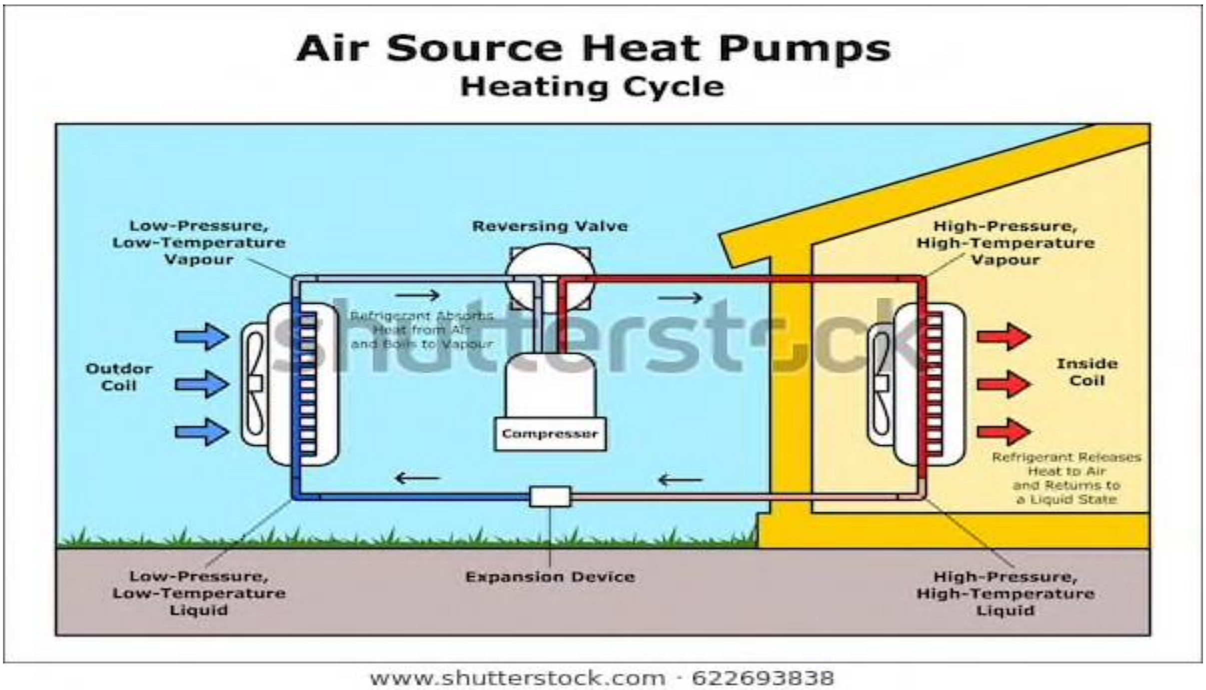
As mentioned above, the air to water heat pumps normally have a SCOP of around three, but the latest models tend to be even more efficient, and in the range of a Danish supplier's models, the SCOP goes up to 4,8 ("Luft Til Vand Varmepumpe » Montering & Installering Af Varmepumpe" 2020). To exemplify the SCOP is set to 4 in this study. This means that a household with a heat energy consumption of 20.000 kWh per year needs to consume 5.000 kWh of electricity. With a current price of 2,19 DKK for a kWh, not including the subscription fee of 39 DKK a month ("Køb El" 2020), the annual costs of the heat energy consumption in this example are 10.950 DKK.

It is not required by law to have annual servicing on the heat pump, but it is recommended by professionals. The cost of an annual service by a Danish plumbing company is 2.295 DKK ("Service Udført Efter Producentens Anvisninger" 2020).

As for the geothermal energy system, the air to water heat pump's carbon emission is dependent on the weather since it runs on electricity. The air to water heat pump emits 150 grams of $CO_2$ x 5.000 kWh = 750.000 grams or 0,75 tons of $CO_2$

### 5.7.3 Air to Air Heat Pump

As the air to water heat pump, the air to air heat pump consists of two units: an outside and an inside unit. The outside units work in similar ways in both heat pumps, but instead of warming up water for the radiator system, the inside unit of the air to air heat pump warms up the air and blows it out into the house. The air to air heat pump works independently and is not connected to any existing system in the residence. This also means that the air to air heat pump does not have heating units in every room in the residence like a radiator pipe system has radiator units in every room. Thus, the air to air heat pump's single unit needs to heat the entire residence.




It is possible though, to install an air to air heat pump system with more inside units. Since the air to air heat pump is not connected to any existing system in the residence, it also means, that it is not heating domestic consumption water, but only heats the air inside the residence. An air to air heat pump can also be reversed and function as a cooling system in the warm season ("Sådan Fungere En Luft Til Luft Varmepumpe - Klimacenter" 2020).

According to Danish Standards 469:

"*Heating and cooling systems must be projected so that it is possible to maintain a satisfactory thermal indoor climate for individuals in the building in consideration to the usage of the building and the individual rooms*" (Dansk Standard 2013, 14)

And

"*The heating system must be dimensioned for a domestic water heating with a hot water temperature from the water heater of 55 °C and a cold-water temperature of 10 °C at tapping of domestic water with the dimensioned waterflow*" (Dansk Standard 2013, 17)

This means, that a heating system must be able to control the temperature in the individual rooms of a building and that it also needs to heat domestic water. Thus, an air to air pump can only function as a supplement to an existing heat system e.g. gas or an oil boiler system.

The costs of installing an air to air heat pump vary. At a Danish air to air heat pump supplier, an air to air heat pump with one inside unit can be purchased in the range of 11.000 – 30.000 DKK, installation included ("Luft Til Luft Varmepumper Fra Panasonic - Stort Udvalg." 2020). An extra inside unit can be purchased for around 3.000-4.000 DKK, including installation ("Varmepumpe Panasonic-MULTI 2-5 Indedele" 2020)

The SCOP of the air to air heat pumps varies, depending on the model. At a Danish supplier, the SCOP of the different models varies from 4,1 to 6,2 ("Luft Til Luft Varmepumper Fra Panasonic - Stort Udvalg." 2020). To exemplify, this study will set the SCOP to 5. A typical Danish household of four individuals uses an average of 292 m³ of natural gas to heat domestic water ("Sammenlign Dit Forbrug Til Opvarmning Af Vand | Ørsted.Dk" 2020). Given that one m³ of natural gas provides 11 kWh ("Gasprisguiden.Dk Sammenlign Med Anden Opvarmning" 2020) a typical Danish household of four individuals consumes 3212 kWh annually for domestic hot water. Since the air to air heat pump cannot heat domestic water, this consumption needs to be subtracted from the total of 20.000 kWh a year, which means that the air to air heat pump must produce a total of 16.788 kWh per year if 100% of the heating in the residence is done by the air to air heat pump.

# 6.0 Actor-Network Theory

As explained throughout this report until now, the field subject to this study, consists of a variety of different aspects. Multiple technologies are involved e.g. old technologies that preferably will be replaced, new technologies that emits less greenhouse gasses, the houses the technologies need to be installed in, the house owners, the municipality, some legislation, etc. All of these aspects seem to affect one another. The municipality wants technologies replaced, in the houses that are owned by the house-owners and while trying to do so, the municipality needs to follow current legislation. When trying to describe an analyze what is going on in this mess of entities and how they all affect one another it is beneficial to do so through the lens of Actor-Network Theory.

## 6.1 Ontology

Actor-Network Theory, or ANT, perceives society as heterogeneous networks consisting of a variety of actors. The actors in the network can be all entities that make up a social setting e.g. artifacts, humans, organizations, and legislation. Actors that are connected, thus influencing and affecting one another. Not only do they affect one another in a positive manner. At times, they also work against one another. Almost like a power struggle. Thus, the network at that particular social setting ends up only consisting of the necessary entities, which have been able to resist one another. These power struggles are ongoing and never ceases to exist, making any actor-network dynamic and changeable (Law 1992).

From the perspective of this study, a network could consist of the house owner, the house, the boiler, the municipality, the government, the heat supply company, the legislation, and so on. When either one changes the other parts of the network get affected by this change and need to accommodate in order to be an actor of this particular network in the future.

## 6.2 Epistemology

ANT authors argue that knowledge is produced in this interaction between the actors in a network rather than by, in the words of Law, the operations of a privileged scientific method. Knowledge is instead a social product, generated by the process of the social network, where all its actors try to make it off on their own, are interwoven in a network that overcomes their resistance and holds them back from breaking out on their own. The knowledge often takes the form of communication in some way, being a paper, a presentation, or a talk, but what the knowledge comes from, is the social process of forming heterogeneous networks (Law 1992).

Taking on the spectacles of ANT, the authors of this thesis must study the process that constitutes the field of study. Which actors are present? How do they affect one another? How do they try to break off on their own and how are they juxtaposed into a patterned network? Moreover, how does it affect the network when the balance between the actors changes and how can change be applied to constitute a network that is more sustainable in terms of carbon emission from private residences.

## 6.3 Agency

A central concept when dealing with ANT is *agency*. ANT takes a different position on this than most other theories on the human-technology relation, where humans are seen as superior to the technology or as the one controlling the technology. In this view, humans are given more value than technology in the relation between the two. ANT, on the other hand, takes the view that humans, technology, or any other actor in the network, by default share the same amount of value or the same *agency*. One does not drive the other. They are simply a node in the network and would not exist in that particular network without the other (Law 1992).

From the viewpoint of this study, this means that all the actors, being human or non-human, should be considered to have *agency* in the network. In this particular network the house owners, the house, the heat supply, the municipality, and the legislation would not exist without one another. Surely, the actors would exist on their own, the house owner still lives on taking care of his or her family, job, leisure, and so on. The house is still standing, the heat supply still produces heat, the municipality still takes care of its citizens, etc. On their own, the actors still exist, but in this particular network, they all rely on one another to exist.

## 6.4 Punctualization

When looking at a network, each node of the network can often be perceived as a network of its own. The house owners are humans, that consist of limbs, organs, blood vessels, and nerves. The gas boiler consists of gas lines, a burner, and a pot. The house consists of a foundation, bricks, walls, and roof, et cetera. How is it, that these networks become a node in another network and not an expansion of that network? These networks seem to be invisible until one or some of their parts break down. We simply see the human, the house, or the gas boiler and they are perceived as a single unit rather than the sum of their parts. Networks that are widely and generally performed, are those that can be considered as a unit rather than a network, thus they can be *punctualized* and considered a resource or a node in the respected network. It has been noted, in this regard, that all networks are precarious. To *punctualize* a network is not to say that it is resolute or set in stone. It is still subject to resistance from both outside and within. To *punctualize* networks within a network can help to determine what is relevant to unfold, thus scoping the respected network (Law 1992). In this study, *punctualization* can help to determine which networks can be *punctualized*, thus scoping the extent of the network in this study. Not only will this study determine which networks can be *punctualized*. It will also investigate which networks, that have already been *punctualized* and profitably can be unfolded and challenged in the perspective of implementing more sustainable solutions in private residences.

## 6.5 Translation

The scientist Michel Callon is the person behind the term *translation processes* in Actor-Network theory. The term involves that there will be a range of processes in a network, where actors and actants will be examined on how they unfold themselves in the network.

In 1986 Callon wrote “Some elements of a sociology of translation: “Domestication of the scallops and the fishermen of St Brieuc Bay”. In the book, Callon illuminates the theory that the scientists used which he describes as Four Moments of Translation.

The first moment we will look into is *problematization*, this moment defines the problem in the network. In this part of the moment, there will be an actor(s) which will be defined as the *obligatory passage point*. *The obligatory passage point* is the place in the network where actors should get through to unfold them as much as possible. The actor(s) which is the *obligatory passage point* is vital for the network to sustain it and the *obligatory passage point a*ctor(s) is identified through negotiations, however, actor(s) of the *obligatory passage point* can also occur in the processes of the network (Callon, 1986, s. 6)

The second moment is *interessement* and describes a chain of processes where the actor(s) and actants sought to lock other actors into the network and tries to lock them into the roles that have been proposed to them. This could, for instance, be how the municipality tries to create an interest in lowering carbon dioxide through collaborations with heat suppliers or companies that energy-renovate. It could for instance also be how the state creates *interessement* through different grants for household and companies (Callon, 1986, s. 8)

The third moment is *enrollment* which describes a set of strategies where the actors try to define and organize different roles which are allocated to others and still have a relation to each other (Callon, 1986, s. 10)

The last moment is *mobilization*, this moment describes how actors in the network ensure that the spokesman represents the relevant collectives properly and therefore is not betrayed later on (Callon,1986). In our case, it could be an actor from the homeowner's association who represents a certain chain of houses in Fløng. A *spokesman* should be able to represent various individuals, the more people the *spokesman* represent describes how strong the network is. The translation processes give the network stability, and if the actors do not work together then the network can decompose.

## 6.7 Inscription device

In the book Laboratory Life Bruno Latour and Steve Woolgar describe how scientist used graphics and speeches to convince each other (Latour and Woolgar, 1986). This describes the term *inscription* which contains how anything can be transformed into different data through *inscription devices*, in the book the element changed from physical into mathematical numbers and graphics to convince other scientists to contribute to their research (Latour and Woolgar, 1986). *Inscription devices* are also present in our case, here the different scientist has transformed physical elements as Carbon dioxide into graphics and number which illuminates the influence of pollution humans have on the world. Furthermore, how we through numbers and graphics, could change Carbon dioxide-emissions in the upcoming years with different green energy initiatives.

When there is an agreement in the network and the involved actors are represented by the *spokesman* and the *obligatory passage point* work, then there is obtained *alignment.* When there is an agreement in the network, thus can the network be mobilized and therefore can the goal be realized.

The purpose of the theory is to understand and map actors in the field, where we intend to use the concepts in translations process by Michel Callon to investigate energy renovation and the readjustment to more environment-friendly solutions.

## 6.8 From Matters of Fact to Matters of Concern

As described above, actor-network theory perceives the world as heterogeneous networks consisting of actors with equal agency. Furthermore, actor-network theory tries to objectify parts of a network by *punctualizing* a bundle of actors that together makes up a stable network, and as a result of this stability appears as a single actor. Now, this perspective may seem as everything is reduced to a point. Even human beings.

This is the traditional actor-network theory standpoint. However, at the beginning of this millennium, Bruno Latour, one of the fathers of actor-network theory, starts to take a different view on how knowledge production. Instead of perceiving the world as existing of objects and clear facts, what Latour calls ‘matter of facts’, those objects and facts should be perceived in regard of what they mean to the world. This is what Latour calls *matters of concern* (Latour 2004)

Let us delve into Latour’s notions. Firstly, what is matter of fact? Latour describes matter of facts as facts that are no longer disputed. facts that through a scientific and/or a historical process have come to a state, where they are no longer questioned and are widely accepted to be the truth. Now, this is knowledge becoming matters of fact. When it comes to technologies, Latour describes matters of facts as objects. When Latour speaks of objects, he refers to them as artifacts that, just as the knowledge, are a product of the process of the making of them, and in the end, the technology is just what it is (Ibid.)

*Matters of concern*, on the other hand, is knowledge being questioned and being put into a context of what it means to the world and the people in it. Knowledge is more than just one truth. Knowledge can have different meanings in different contexts and in different perspectives. As for technology, when speaking of *matters of concern*, Latour describes the technologies as things. When referring to technologies as things, Latour does not simply mean things as in artifacts, but things as democratic constellations. Latour refers to the Scandinavian ting. E.g. the Icelandic parliament ‘Altinget’. This means, that a thing embodies some values besides just being an object. A thing means something to the world and to the people in it (Ibid.)

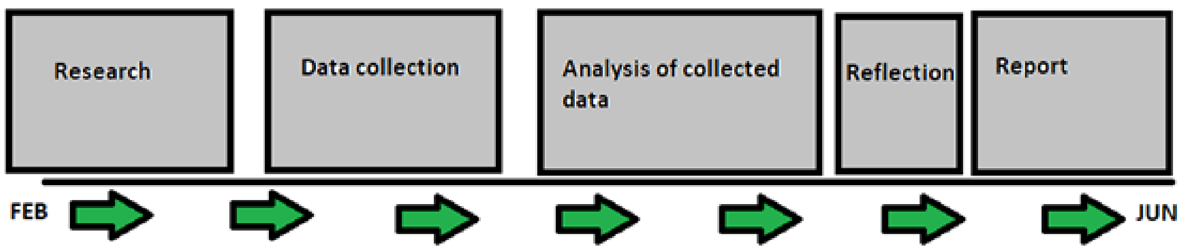
Ultimately, knowledge and technologies should not be perceived as being absolute and certain truths – Matters of fact. Instead knowledge and technologies should be perceived from the perspective of how they concern the world and the people in it. As *matters of concern* (Ibid.)

## 7.0 Methodology

In this section, the methodological framework of this master thesis will be described. Furthermore, reflections of doing fieldwork during the Covid-19 pandemic will be presented.

## 7.1 Project Design

This project design was created to visualize this master thesis and has also acted as a guideline as well as a timeline for this thesis´s process. Furthermore, the project design illustrates the process of this master thesis from start to finish. This master thesis officially started in February 2020.




Each box on the project design illustrates each phase of this master thesis. The first phase of this master thesis is the research phase, where research is conducted to gain insights and essential knowledge about the thesis topic. Once the basic, yet important, research is conducted it is time to collect our own data.

The data collection phase is very essential, as this data will be used to analyze and identify important actors as well as technology. Once the data is collected it is time to start analyzing it.

The analysis of the collected data phase is very important as it is during this phase that the researcher works with the collected data and identify patterns between different informants etc. Furthermore, the researcher obtains an overview of the collected data during the analysis phase.

Typically, after the analysis of the collected data, the researcher reflects upon the project process and gathered data, it is in this phase that the researcher can go back to some previous phases to gather more data or knowledge if necessary. All phases lead up to a final phase which is writing the thesis report.

## 7.2 Research

In this section, a description of the research phase will be presented. Here we intend to look into how we approached our field through meetings with Høje Taastrup Municipality and literature research of significant topics in the field.

### 7.2.1 Meetings with Høje Taastrup Municipality

From a previous project in Høje Taastrup did we know individuals in their climate section. At the beginning of the project, we had some meetings with the climate department at Høje Taastrup Municipality, where they laid out different projects within the municipality. The most interesting project for us was heat supply and energy reduction in Høje Taastrup Municipality. In the second meeting with Høje Taastrup Municipality they presented the case and the field we could investigate, hence upon different studies in the field and which former projects there have been launched in the area of Høje Taastrup Municipality and the topic of heat supply, subsequently we focused on the area of Fløng because we wanted to investigate single-family houses and Fløng was also interesting to examine because of the heat supply was mainly natural gas and oil.

### 7.2.2 Literature Research

The research we made through the project did begin with a presentation of topics of the field given, through the meetings with Høje Taastrup Municipality. There have been many different studies on the field which made it clear for us on what to research. The first step towards an understanding of our field was to comprehend the different technologies to energy renovation and for heat supply. Thereafter, we looked into previous studies of household owners and energy consumption in single-family households. It was also important to look into this field in a broader manner, therefore we looked into areas as legislation, politics, and different goals for energy consumption in the future. Previous projects in this field have been studied in order to get different insights into problems in this specific field.

The literature research gave us a broader understanding of our field and which areas we could investigate, especially areas where we could use our background as techno-anthropologist. The research made it clear for us that we should incorporate energy renovation in our investigation to understand the energy reduction comprehensively. This ended with a literature review on the field which is described earlier.

## 7.3 Data Collection

In this section the methods used during the data collection phase will be introduced and further described to give the readers of this master thesis an understanding of the methodology used.

### 7.3.1 Interviews

Interviews are effective when the researcher wants a detailed understanding of informants´ ideas, attitudes, opinions, motivations, and experiences (Schjødt and Nielbo, n.d.). Interviews are an essential method when doing research about users, as it is most beneficial to talk with the relevant actors themselves (Schjødt and Nielbo, n.d.).

The structure of an interview is quite simple, as it is a conversation between interviewer and respondent, however, there are different types of interviews (Schjødt and Nielbo, n.d.). The quality of the interview can be improved by using additional tools such as an interview guide, which helps to adhere to a certain structure of the selected type of interview (Schjødt and Nielbo, n.d.).

The advantages of interviews are that the interviewer is able to ask individual questions to his respondents, which makes the data more valid and more usable, as the researcher is essentially able to ask the right questions to the right actors (Schjødt and Nielbo, n.d.). Furthermore, the interviewer can ask detailed questions, and adjust the questions based on the answers of the respondent (Schjødt and Nielbo, n.d.). The disadvantages of interviews are that interviews are often time-consuming, and it can be hard to get respondents (Schjødt and Nielbo, n.d.).

### 7.3.2 Semi-Structured Interviews

In this master thesis, the type of interview used to gather data has been the semi-structured interview type.

The semi-structured interview is an interview type, where the interviewer uses an interview guide to structure the interview (Schjødt and Nielbo, n.d.). The interview guide is, typically, a document containing the research questions that the interviewer wants to address during the interview (Schjødt and Nielbo, n.d.). An interview guide is often used in relation to a semi-structured interview where it is used as a guideline for the interview (Schjødt and Nielbo, n.d.).

During a semi-structured interview, the interviewer uses their interview guide as the base of the interview, the interview guide acts as the structure of the interview (Schjødt and Nielbo, n.d.). However, in this type of interview, the interview can go beyond the research questions, which makes this type of interview a semi-structured interview, as it is not as rigid as the structured and not as freely as the unstructured interview (Schjødt and Nielbo, n.d.). The order of the question may vary, and the interviewer can ask in-depth questions, furthermore, the interviewer can give the respondent a possibility to answer the questions freely, which sometimes gives useful insights that are valuable in relation to the research topic. (Schjødt and Nielbo, n.d.). The semi-structured interview is useful when the interviewer only has the possibility to interview the participants once, thus want to make sure all research questions are addressed during the interview (Schjødt and Nielbo, n.d.).

Interviews were used in this thesis project to gather information from important actors such as experts and house owners from Fløng. By interviewing experts and house owners from Fløng important data was obtained which is the basis of this thesis project. The reason why house owners in Fløng were interviewed was that they are the end-users, and thus their voice has significant value in this project. All interviews have been conducted in Danish and as for the citations used in this thesis, they have been translated to English in correspondence with the language of this Thesis.

### 7.3.3 Participant Observation

In this master thesis, participant observations have been used to identify a very detailed understanding of the actors´ behaviors, practices, motivations, and opinions (Schjødt and Nielbo, n.d.). The goal of participant observation is to observe as many details of an event as possible, which can be used to identify how actors behave in a certain event (Schjødt and Nielbo, n.d.).

In relation to this master thesis, participant observation was used to some extent. The initial intention was to apply the observation method more, however, due to the sudden lockdown of Denmark due to the Covid-19 pandemic, it was only possible to use observation prior to the lockdown of the country. The observation was used in relation to meetings with Høje Taastrup Municipality, as well as during meeting with an Expert, where a tour of his workplace was given, again prior to the lockdown.

### 7.3.4 Survey

In this master thesis, a survey was used as a supplement to the qualitative methods used to gather data. The survey was shared on the different Høje Taastrup groups on Facebook that were identified during the research phase of this thesis.

A survey is the most common tool in the quantitative researcher's toolbox (Schjødt and Nielbo, n.d.). A survey can be defined as a quantitative research tool where respondents respond to a questionnaire that is made by the researcher (Schjødt and Nielbo, n.d.). Today, most surveys use a self-administered questionnaire where respondents respond by filling out the questionnaire online (Schjødt and Nielbo, n.d.). The benefit of an online questionnaire is that it can bare shared on social media, reaching out to more potential respondents (Schjødt and Nielbo, n.d.). By finding specific groups on Facebook, it is possible to narrow down the geographic of the potential respondents, this was done to narrow down the respondents to people from Høje Taastrup Municipality as the questions in our questionnaire were specific to people from Høje Taastrup Municipality.

In this thesis, we used Google Forms to create a questionnaire, as we wanted to share the questionnaire on the identified Høje Taastrup groups on Facebook.

The following table shows which groups the survey was shared in and how many members the specific group has:

| Platform | Group Name | Group Members |
|---|---|---|
| Facebook | "Du ved du er fra Taastrup når…" | 7.000 |
| Facebook | "Vores by Hedehusene" | 3.800 |
| Facebook | "Hedehusene info gruppe for alle" | 2.400 |
| Facebook | "Det sker i 2630 Taastrup" | 5.700 |
| Facebook | "Alle os i Taastrup" | 4.600 |
| Facebook | "Høje Taastrup og omegn info og hjælp" | 1.300 |
| Facebook | "Landsbylauget- Fløng Sogn" | 2.500 |

The following table shows the content of the questionnaire that was shared in the above groups:

| Page | Content |
|---|---|
| 1 | An introduction to the questionnaire |
| 2 | Information about the respondents and their household |
| 3 | Sustainability and Climate |
| 4 | Energy renovation |
| 5 | Heat Supply |
| 6 | Final questions |
| 7 | Thanks for help and feedback |

The questions in the survey are based on information gathered during interviews with our informants. The purpose of the survey is to find out if the statements from our informants are the consensus of the people living in Fløng. The total amount of responses to our survey is 66. The language of the survey was Danish, the reason for that was because the target group was members of the aforementioned Høje Taastrup-Facebook-groups. The data we have used in this report have been translated to English to correspond with the language of this thesis.

## 7.4 Analysis of Collected Data

In this section, the methods used during the analysis of the collected data phase will be introduced and further described to give the readers of this master thesis an understanding of the methodology used.

### 7.4.1 Transcription of Interviews

In this master thesis, we have chosen to transcribe all our user interviews, as a textualizing of our interviews will be beneficial when analyzing the data, we have gathered.

Transcription means converting audio recordings from speech to text (Schjødt and Nielbo, n.d.). It is crucial in terms of the analysis of the interview data that the interviews are transcribed so the researcher can gain an overview of the data collected (Schjødt and Nielbo, n.d.).

It is necessary to transcribe the interview to do a content analysis of the interview (Schjødt and Nielbo, n.d.). Transcription of interviews is very time consuming, according to Schjødt and Nielbo it takes five to ten minutes to transcribe one minute of an interview (Schjødt and Nielbo, n.d.).

### 7.4.2 Coding the Transcriptions

After transcribing the interview, the next step is to start identifying themes in the textualized interviews. The themes are then color-coded, which gives the researcher an overview of each theme among the interviews and illuminate different patterns in the generated data. By color-coding the transcriptions, it becomes easier to find specific quotes that can be used in the analysis.

The following is an example of a transcription that has been color-coded: I= interviewer, H= informant (Hans, user):

H: Ja fordi vores gamle bestod jo med de her elvarmepumper, men fordi der var en enkel el radiator der stod tændt i badeværelset så hedder det at vores primære opvarmnings kilde var el opvarmning. Så sagde jeg jamen så piller jeg den ud, men så kunne de ikke sige hvad min rating så ville være.

I: Hvad kunne så få dig til at skifte når det en gang var tid til det?

H: Vi har nogle venner der lige har bygget hus så vil gerne lige høre der erfaringer med sådan en pumpe der, og så følger jeg med i vild med villa hvor der generelt er artikler om sådan noget for at holde mig opdateret på hvad er markedet som det er nu. Jeg har ikke lyst til at være firstmover for noget for så at finde ud af det var måske ikke den rigtige vej.

I: Så du vil gerne lige vente lidt og se?

H: Ja, jeg vil lige se markedet an. Jeg er ikke den sidste der skifter, men jeg er heller ikke den første.

I: Hvilke kriterier ligger du så vægt på?

H: At det bliver billigere at bruge over tid. Så det med at det kan tjene sig ind igen på 5 år- 7 år eller 10 år. Så kan jeg godt se en idé i at investere i en dyr løsning, men som så giver noget tilbage over tid.

*Example of transcription and color-coding of the transcription*

Transcriptions Can Be Found in Appendix 8

### 7.4.3 Personas

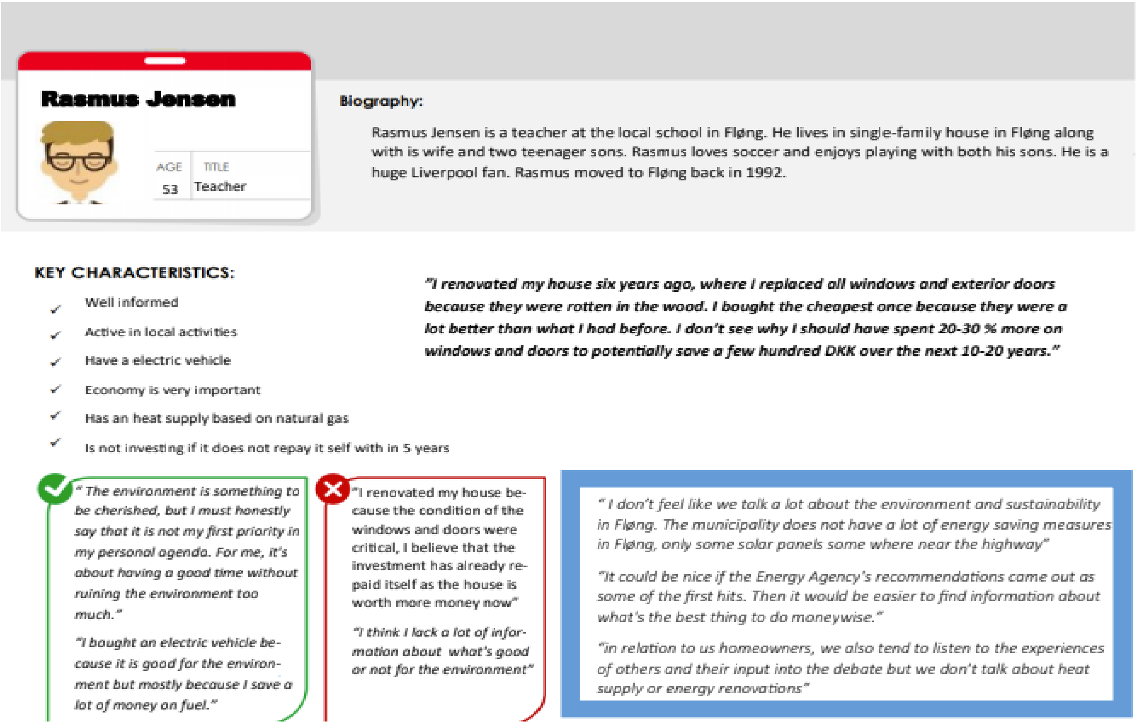
This part of the method contains a description of personas and how it will be used in the report. The section of personas is created so that the municipality can accommodate the needs of the citizens. There will be an example of a created personas from our generated data in this section.

Through our generated data from the informant and the analysis, we intend to create personas. A persona is a fictional person who can identify with already existing persons in the field ("Hvad Er Personas | Flex Media" 2020). Personas is used to represent prominent types within a group of people. In this study, Personas will be used to convey the findings to the municipality. By applying Personas to convey the findings to the municipality, the house owners become real people that the municipality may relate to. This can make it easier for the municipality to understand the house owners and what drives them in regard to taking sustainable actions on their houses. Furthermore, the municipality can use the Personas as a design tool. Personas can be a very powerful design tool. If the municipality chooses to use the Personas as a design tool, they must choose to design for only one of the Personas. Making the design personal.

The process of using Personas as a design tool, is to choose the one persona that does not eliminate the other, when designing to that specific Persona. Throughout the whole design process, the municipality must keep coming back to the chosen Persona, to remember that is who the municipality is designing for (Grudin and Pruitt, 2002) (This creation of a persona can help us and the municipality to better understand the house owners. ("Hvad Er Personas | Flex Media" 2020) Through the method of personas, it is easier to create a more relevant message for the end-user, mainly because the sender (municipality) knows the house owners better though the created personas from data gatherings and therefore accommodate them better ("Hvad Er Personas | Flex Media" 2020). Since all human beings are not alike it is necessary to create different personas to represent different kinds of persons. The method of personas opens up different ways to approach the customer, in our case the house owners ("Hvad Er Personas | Flex Media" 2020). It is necessary to look at the values of the individual to create a persona, but demographic information can also be valuable such as job situation, education, age, etc. ("Hvad Er Personas | Flex Media" 2020).

We intend to use personas to create a more comprehensive understanding of the house owners and how the municipality should approach them through the gathered data of the citizens. Which could be questioned as to what their interests are? What their motivation is with energy renovation? What is their struggle with energy renovation? etc. The personas we created can make it easier for the municipality to understand the house owners and additionally make it easier to communicate and therefore create a greater interplay between the house owners and the municipality.

The following persona is created through the generated data in Fløng:




*Example of one of our Personas*

Additional Personas Can Be Seen In Appendix 4, 5, 6, and 7.

## 7.5 Reflection

In this section, some reflections upon the project process will be presented

### 7.5.1 Doing Fieldwork in a Pandemic

In March 2020 Denmark officially locked down due to the Covid-19 pandemic. This pandemic has affected the whole society as well as the fieldwork in this master thesis. In this section, it will be described how the Covid-19 crisis in Denmark has affected this master thesis, along with how the authors of this master thesis quickly had to adapt to the situation and use digital tools in order to collect the data necessary for this thesis.

The sudden lockdown of Denmark meant that the university closed, and the government advised to practice social distancing to stop the spread of the virus. Practicing social distancing during fieldwork is very unfortunate. Nevertheless, we had to adapt our methodology. We were at the beginning of our data collection phase when the lockdown was initiated. We had already interviewed one expert, however, we needed to interview users from Fløng. Initially, we had hoped to interview our users in their house, so that we could observe and see their house and heat supply systems, but due to the lockdown this was not possible.

Due to the social distancing, we were not allowed to meet with any informants physically, thus we decided to use digital platforms to find and interview informants from Fløng. We quickly identified a Facebook group called*: Landsbylauget - Fløng Sogn.* We applied for a membership in this group and was quickly given access to its almost 2.500 members. Through the Facebook group, we found our informants, which we interviewed digitally through Skype or over the telephone.

oing data collecting digitally, had both benefits and limitations. Benefits such as due to the lockdown informants had time to be interviewed. We got great feedback from the Facebook group in Fløng where we had 7 users who offered their help by volunteering for an interview. However, the digital data collection also had its limitation such as lack of observations and the lack of possibility of more user involvement in the form of workshops etc.

The pandemic has affected this thesis but has also been beneficial as we quickly found informants through Facebook which we then interviewed through Skype or via Telephone.

## 7.6 Overview of Informants

In this section, an overview of informants will be presented as well as a description of how the informants were found. Additionally, a description of how the identities of the informants are dealt with will be presented.

In this master thesis, all informants are fully anonymized to keep our informants´ identities safe as their identities are not relevant to this thesis. This means that all names of our informants are aliases and not their real names.

Most of our user informants were found through Facebook on the Fløng Facebook group. Due to Covid-19 we were forced to use digital tools to interview our informants. All user interviews were conducted digitally, either through Skype or via a telephone, as well as the expert interviews, with an exception of two experts, which is stated in the table below:

| Name | Function | Age | Type of House | Primary Heat Supply | Energy Label on their house | How was they interviewed? |
|---|---|---|---|---|---|---|
| Carsten | User | 72 | Detached single-family house in Fløng | Liquid Fuel, Oil | - | Telephone |
| Mikkel | User | - | Detached single-family house in Fløng | Natural Gas | D | Skype |
| Jens | User | 37 | Detached single-family house in Fløng | Natural Gas | C | Skype |
| Hans | User | 40 | Detached single-family house in Fløng | Natural Gas | C | Telephone |
| Nichlas | User | - | Detached single-family house in Fløng | Natural Gas | - | Telephone |
| Daniella | User | 55 | Detached single-family house in Fløng | Natural Gas | - | Telephone |

| | | | | | | |
|---|---|---|---|---|---|---|
| Torben | User | 58 | Detached single-family house in Fløng | Natural Gas | - | Skype |
| Palle | Expert | 60 | - | Natural Gas and Heat Pumps | - | Skype |
| Marcus | Expert | - | - | - | - | Skype |
| Ulf | Expert | - | - | District Heating | - | Telephone |
| Nico | Expert/ Techno-Anthropologist | 31 | - | - | - | In Person |
| Steve | Expert | - | Detached single-family house in Fløng | Natural Gas | - | In Person |

## 7.7 Reflection of the Project Design

In this section, a reflection upon the project design will be given.

The first illustration of the project design did in fact not portray the process of this thesis, as the project process has not been a linear process, but an iterative process as illustrated in the revised project design.

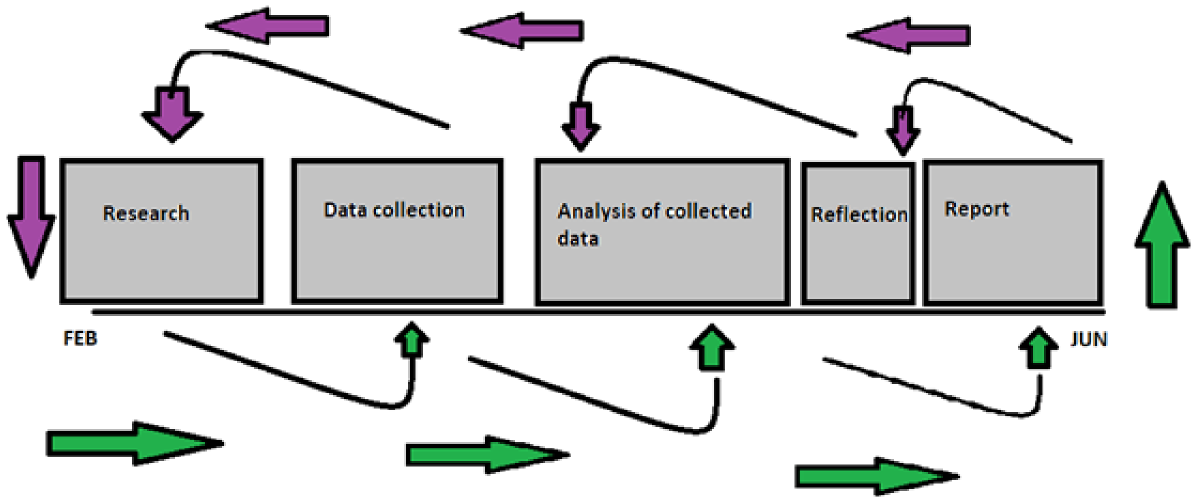



*Illustration of the iterative project process*

During the project, it was quickly identified that the process is not linear as portrayed in the first illustration. The process of this thesis has been iterative as it was needed to go back and forth between phases, one of the reasons being that during a continuous reflection it was identified that more data or more research was needed, etc.

# 8.0 Analysis - Four Moments of Translation

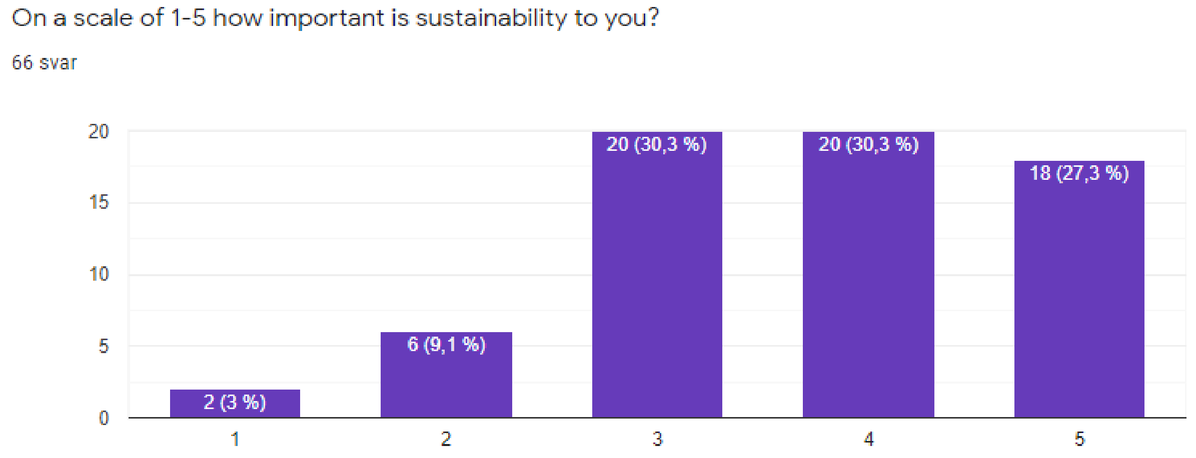
This analysis will primarily be based on the qualitative data retrieved by interviewing house owners in Fløng. Subsequently, as a supplement to the qualitative data, this analysis will draw on the quantitative data retrieved from the survey conducted among the users of various Facebook groups about different communities within the municipality of Høje Taastrup.

The structure of this analysis will be based on actor-network theory as described in chapter 6. Firstly, the data will be analyzed from the perspective of Latour's notion of *matters of concern* to identify the concerns of the house owners in Fløng regarding sustainable solutions on their residences. More exactly, the approach will be to identify the discrepancies of matters of concerns within the network. For example, what is considered matters of concern by the house owners but matters of fact by other actors in the network. Secondly, the identified concerns will be analyzed in the perspective of Callon's notion of translation processes, to establish how the network can be stabilized in order to promote the implementation of sustainable solutions to single-family houses in Fløng. Lastly, an *alignment* analysis of the network will be conducted in order to assess the stability of the network.

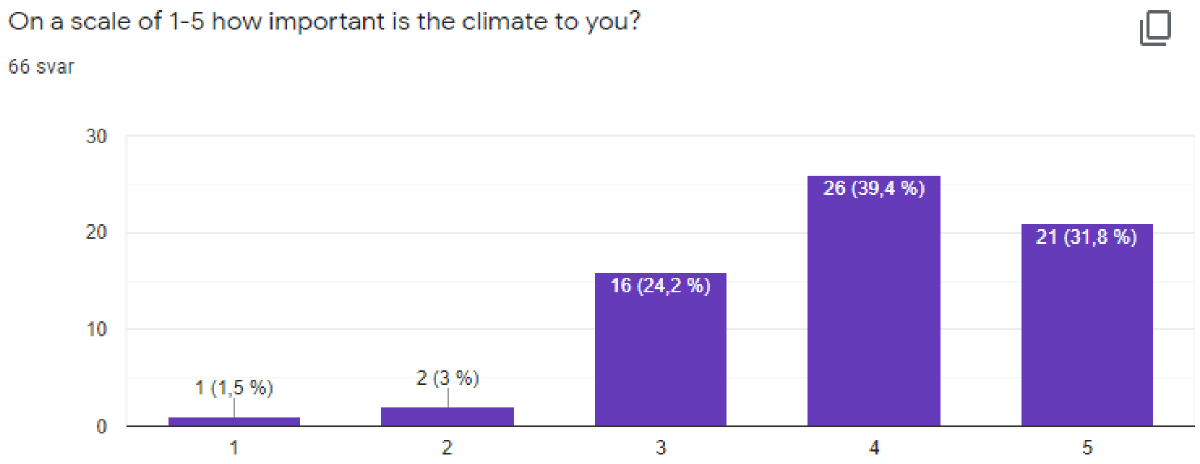
## 8.1 Matters of Fact and Matters of Concern

Overall, the informants in this study widely agree, that climate and sustainability is of great concern. All the interviewed house owners agree, that taking actions on behalf of the climate is generally a good thing. This also shows in the survey.

On a scale from 1-5 (5 being the most), more than 88% answer at least 3 when being asked how important to them sustainability is.




The answer is even clearer when sustainability is replaced with climate. Now, more than 95% answers 3 or above.




This seems to be a sound foundation on which to build a municipal greenhouse gas reduction project upon. Both the municipal and the house owners of Høje Taastrup have the same concerns regarding the climate and sustainability. So why is it that the houses in Fløng are still connected to supply sources fueled by fossil fuels?

The municipality of Høje Taastrup has already tried to implement the collective district heating in Fløng but did not succeed. When launching such a project, the municipality needs to follow the heat supply legislation, which, in far most cases, means that the municipality will try to implement district heating. For multiple reasons, a gross group of house owners is not willing to submit to the district heating projects. More on these reasons later. Overall, the house owners have some concerns about such a project. Thus, what in other parts of the network is considered *matters of fact* – the heat supply legislation – is to the house owners considered a matter of concern.

Now to the reasons why the house owners have some concerns. When submitting to the district heating project the house owners must make an investment to connect the house to the district heating grid. And even though the house owner may save some money and the investment as a result of that will be repaid over time, the house owners often feel it is too big an investment compared to the repayment rate. This shows that the house owners have some economical concerns regarding the collective district heating, that to other parts of the network is simply perceived as *matters of fact*. To the house owners, the investment and the repayment rate is matters of concern.

Another reason for the failure of the district heating project in Fløng was misinformation provided by the authorities about the economy for the house owners. This led to the house owners feeling misled and deceived by the municipality and the interviewed house owners in this study still talks about this. Also, the house owners talk about another public case. The case about solar panels, where the authorities changed the rules and removed the advantageous deal for those who invested in solar panels. These cases have caused some concern among the house owners when it comes to trust in the public administrations.

When interviewing the house owners in Fløng, a recurring issue is that the collective district heating often comes with obligations. The house owners can either be obligated to connect to district heating or they can be obligated to stay connected. This is also one of the main reasons why the aforementioned project failed. There was a great resilience towards the projects because of the obligation to connect. Thus, several of the house owners interviewed in this study, prefer to have ownership of their heat supply solution. Thus, the obligations make the collective solution of district heating a matter of concern to the house owners.

If a house owner in Fløng wishes to connect to the district heating, the house owner must accept to let his property undergo some excavation. In order to connect the house to district heating. The house's pipe system must be connected to the district heating grid. This means, that parts of the property need to be excavated to lay down the pipes between the house and the district heating grid. This excavation is an inconvenience to the house owners and a matter of concern that needs to be taken into consideration.

Considering the collected data from the perspective of *matters of concern*, the following concerns have been identified:

- Høje Taastrup Municipality and the Heat Supply Act
- The House Owners and Investments
- Prior Initiatives have caused distrust
- Obligatory Collective Solution or The Freedom of Owning the Solution
- Inconveniences When Connecting to the District Heating Grid

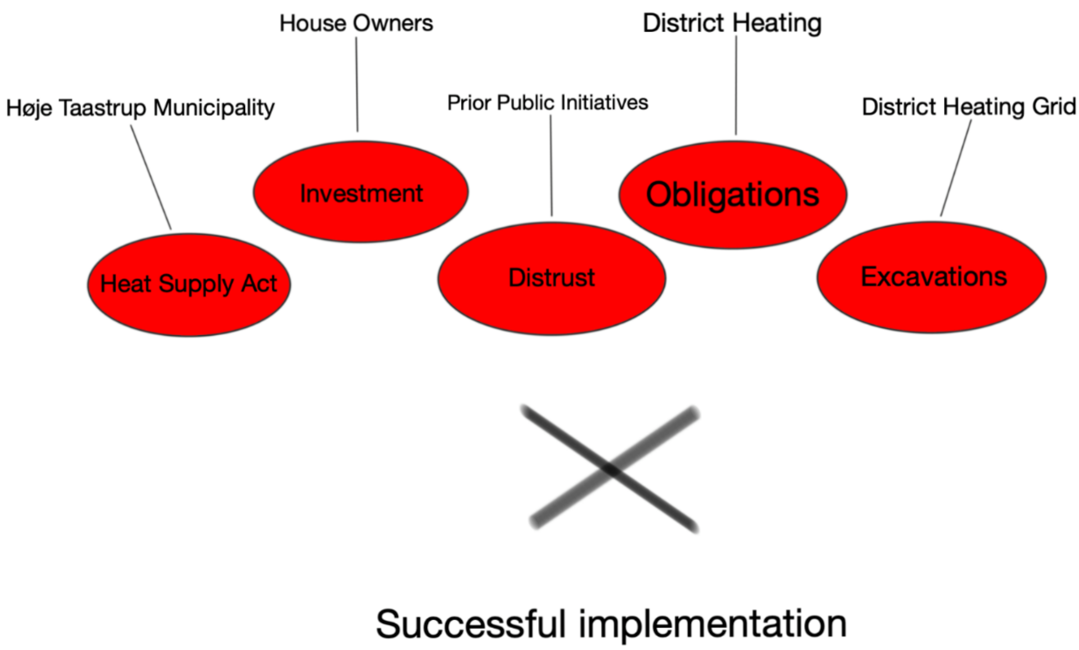



*Illustration of Matters of Concerns that blocks the successful implementation.*

## 8.2 Problematization

In this chapter, the actors central to a municipal project of reducing greenhouse gas emissions in single-family homes will be identified. Also, the interrelations of the actors will be identified, by analyzing the obstacles for the actors' success in reaching their individual goals. Lastly, a common goal for the actors will be suggested, to ensure that the actors can overcome the resistance within the network, thus reaching the overall goal of reducing greenhouse gas emissions within single-family houses in Fløng.

## The Interdefinition of the Actors

This part of the analysis will be based on the five concerns identified above.

## Høje Taastrup Municipality and the Heat Supply Act

Already from an early stage in this study, it became clear that one of the obstacles, from the perspective of the municipality, is the heat supply legislation. According to the heat supply legislation, a municipal heat supply project must rely on a socio-economical calculation. In short, the municipality must choose the most socio-economical beneficial heat supply project at hand. Not necessarily the project that ensures the highest reduction of greenhouse gas emission. As mentioned in chapter 1.5, some typical key elements to the socio-economical calculation are a) expenses to fuel; b) income from e.g. electricity sale at a power plant and c) potential environmental effects from e.g. $CO_2$ and $NO_x$ emission. This means, that the option for a municipal heat supply project is often reduced to the promotion of district heating. As mentioned in chapter 5, district heating plants burn different combust different types of fuel and simultaneously produce both heat and electricity. This means, that the expenses to fuel are relatively low and the district heating plant generates an income from selling electricity as well. In addition to this, more than half of the combustion at Danish district heating plants consists of biofuel, which means that the environmental effects from $CO_2$ and $NO_x$ emissions are relatively low. This may sound like a perfect solution – cheap fuel, income from electricity sale, and environmentally friendly. In reality, this solution does not always find its way to the Danish households. At an initial meeting with the environmental department at the municipality of Høje Taastrup, the authors of this thesis were informed, that the house owners within the municipality seldom find the district heating solution very appealing and therefore choose not to install district heating in their houses. The municipality, some years ago, launched a project in Fløng, that was supposed to implement district heating to the Fløng community. As a part of this project, the main pipe for district heating was buried and a solar panel facility was built on the outskirts of Fløng. The result of the project though, was that almost none of the houses in Fløng was converted to district heating.

Even though the heat supply legislation is supposed to be beneficial to both the socio-economy and the environment, it seems that it, at least in the case of Fløng, is neither. More so, the heat supply legislation becomes an obstruction for progress because the house owners in Fløng show resentment to the proposed solution.

## The House Owners and Investments

If the heat supply legislation is supposed to be beneficial to both the socio-economy and the environment, why do such projects fail to succeed? First of all, the municipality does not have power over the house owners and their houses. Thus, the municipality needs to get the house owners on board with the project. But what drives the house owners to take action and make either energy renovations or replace their heat supply? The answer to this can be given in just one word – The economy. The top priority of the house owners in Fløng is the economy. As Tommy expresses:

*"I would have to gain an advantage of my own. I must save some money on it" (Appendix 8, p. 57)*

When asked about the reason for making energy renovations to his house, whether it is climate or economy related, Mikkel replies:

*"That is because of the economy" (*Appendix 8, p. 44*)*

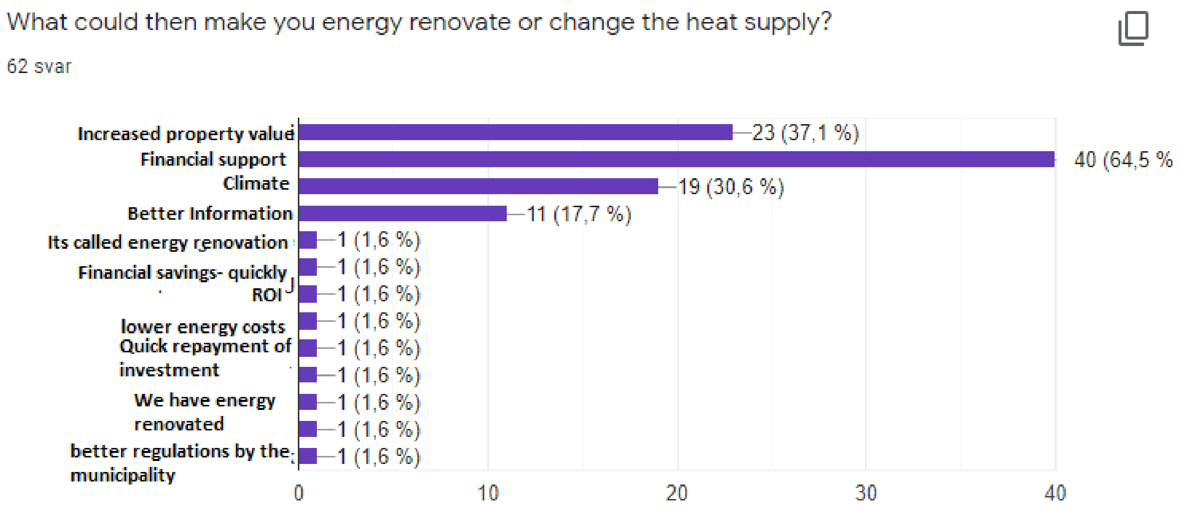
When asked about the reasons behind the actions Hans has taken on his house, Hans replies:

*"That was for the sake of my own wallet. Both the comfort and the wallet"*

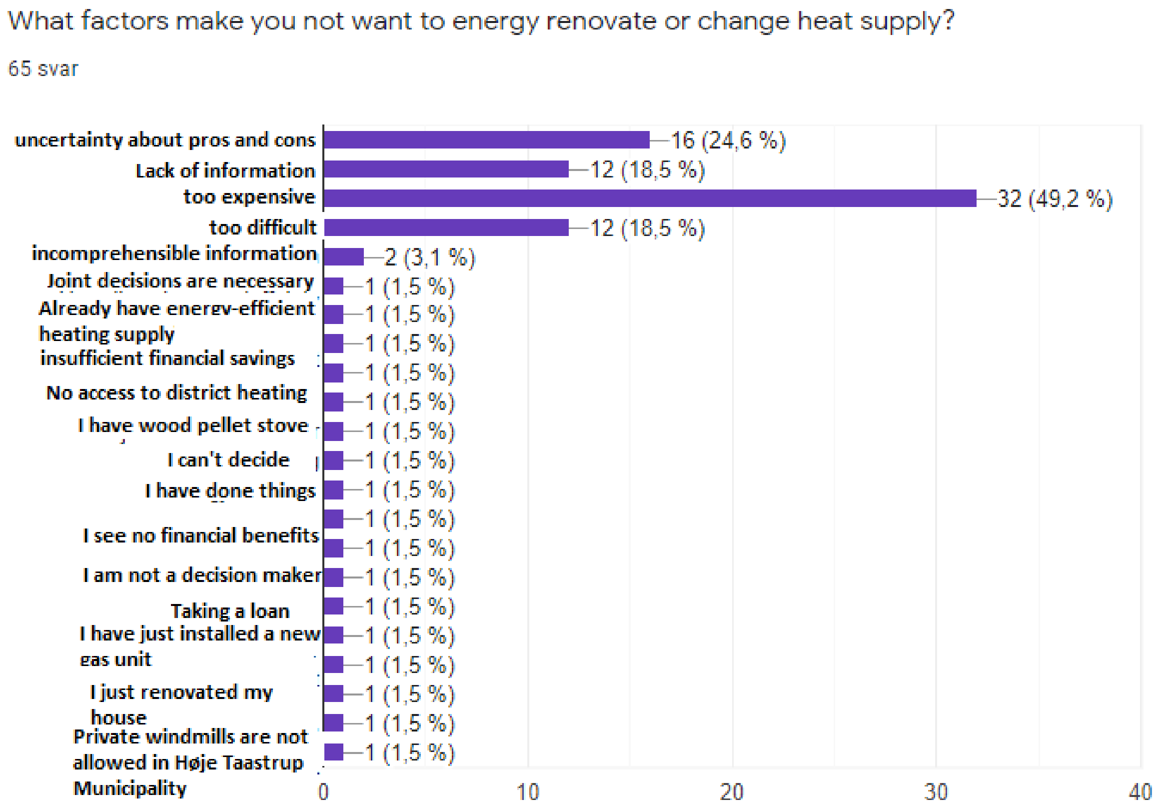
*So, it has to be the economy that makes sense? the interviewer asks.*

*"Yes" (*Appendix 8, p. 17*)*

When asked about which factors could motivate the house owners across the municipality of Høje Taastrup to energy renovate or replace their current heat supply, more than 64% of the informants answer economical support and more than 37% answer increased value of the resident (more than one answer was available to the informants in this question).




When asked about which factors cause the house owners across the municipality of Høje Taastrup, almost half the informants reply that it is too expensive (more than one answer was available to the informants in this question).




For the house owners to get on board on a heat supply or an energy-saving project, the house owners need to accept making an investment in their residences. Either as an energy renovation project, as a replacement of the heat supply or both. As described in chapter 5, such an investment can be quite expensive, depending on the type of heat supply or energy renovation. Not every house owner is ready to make such an investment. As Nichlas, one of the informants in this study expresses when asked about the possibility of a joint solution amongst the house owners in a neighborhood:

*"We are probably too individually. Also, economically. Some may have a tight economy and will not be able to invest 50-100.000 DKK. Some are old and some are young, so it differs who lives here" (*Appendix 8, p. 51*)*

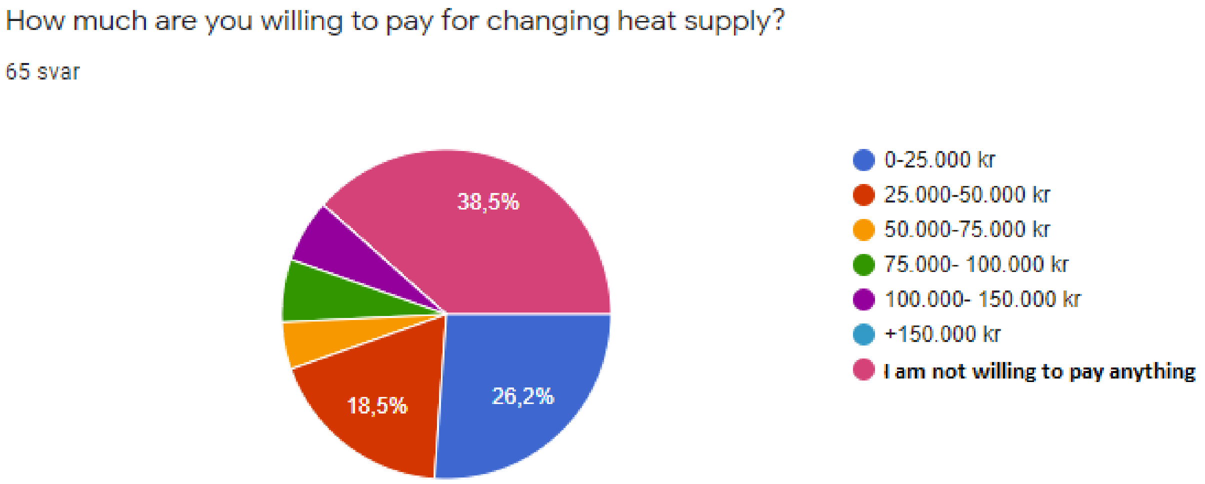
According to Nichlas's statement, house owners can be reluctant to invest for different reasons. Either the current economy of the household or simply because of the age of the house owners. Either because the house owners are young or old. To the latter, the informant Carsten elaborates, when being asked about if he would be interested in obtaining an advantageous loan to finance an investment:

*"No, I would not. My wife and I have always had the principle, that when we turned 60, which is some years ago now, we should be free of debt". Carsten continues: "If we were considering moving, which one does when reaching a certain age, then it would be too much, right?"* *(*Appendix 8, p. 37*)*

Of cause, Carsten's statement is not directly about making an investment, but making an investment through a loan, but whether it is through a loan or not, Carsten contemplates on his age and for how long he will be living in his current house. To Carsten, it is not attractive to make big investments, when he is contemplating on moving within a foreseeable timeframe.

*Torben concurs when being asked about a foreseeable timeframe: "10 years, that is such a long time, then I get old and retired"* (Appendix 8, p. 12)

The willingness to invest, or the lack of willingness, does not only apply to the house owners in Fløng. When asked about how much the house owners in the municipality of Høje Taastrup are willing to invest in replacing their current heat supply, more than 38% are not willing to invest at all, while more than 26% are not willing to invest more than 25.000 DKK




Now, this is all about a one-time investment. As described in chapter 5, replacing an older and less energy-efficient heat supply with a new and more sustainable solution or making energy renovations to a house, saves money on energy consumption. So, how does the house owners in Fløng relate to the prospect of saving money on an investment, so that the investment repays itself over time in saved energy consumption?

To this issue, Hans expresses:

*"(...) 5,7 or 10 years. Then I can see it would be a good idea to invest in an expensive solution, which then repays over time" Hans continues: "In general, not more than 10 years. Everything of electronics and so on gets outdated, so it must not take too long"* (Appendix 8, p. 19)

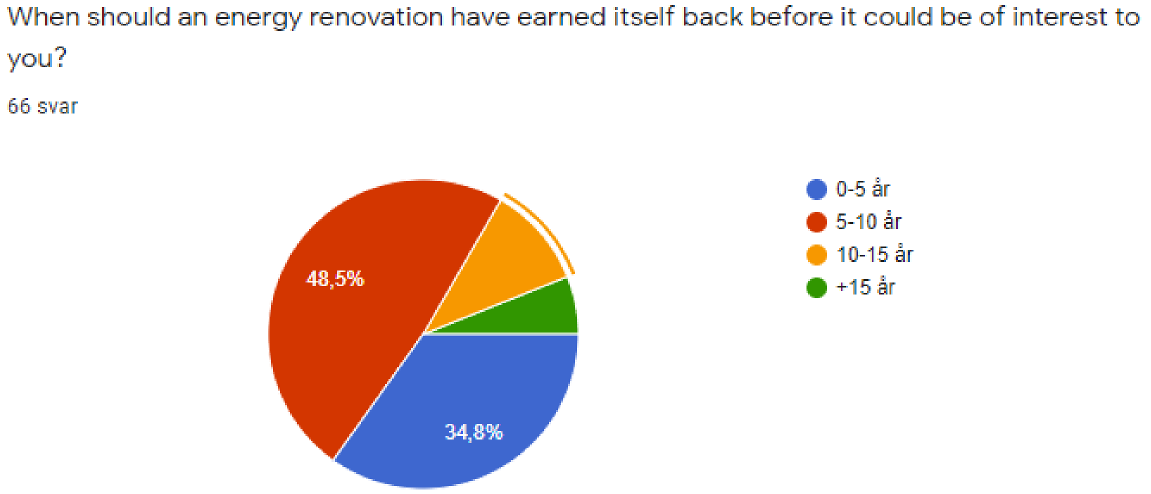
Torben also has an opinion about the repayment rate:

*"Some 5 years I believe. Well, if it is so, that it can be repaid during a 5-year period, then it will be okay"* (Appendix 8, p. 58)

Also, Carsten tells about what he expects of a repayment rate:

*"That depends on the size of the investment. Within 5 to 10 years, then the investment must be repaid".* (Appendix 8, p. 36)

When asked about the repayment rate for an energy renovation, the house owners across the municipality of Høje Taastrup answer as follows: More than 34% within 0-5 years and more than 48% within 5-10 years. That is a total of 83% of the respondents who wants their investment to be repaid on a maximum of 10 years.




In all, this shows that the number one priority of the house owners is the economy. Regardless of how sustainable a solution is or the potential positive effects on the climate. Firstly, it matters to the house owners how they have to invest right here and now. Secondly, the investment has to repay itself and it has to do so within a foreseeable timeframe, which is in far most cases less than 10 years, preferable less. Thus, the motivation for the house owners to get on board with an energy-saving project, they would have to make a profit of their investment on a relatively short term.

## Prior Initiatives have caused Distrust

In 2012, the Danish government introduced a new legislation regarding solar panel systems in private households as well as public buildings. The legislation was a scheme to promote sustainable solar energy in Denmark. The scheme was, that those who invested in solar panels could release their surplus production into the power grid and get the same amount of electricity in return in periods with a deficit power production. In addition to this, the solar panel owners could settle their power consumption once a year, thus getting full advantage of the seasonal conjunctures in power production. This scheme led about 85.000 house owners in Denmark to invest in solar panels. Later the Danish government altered the legislation, making the scheme less profitable for those who had invested in solar panels. Thus, the repay rate on the solar panels was prolonged and a lot of house owners who had invested in solar panels felt they had been deceived by the Danish government.

This has not only affected the 85.000 house owners who invested in solar panels. It also has an effect on how house owners in Fløng perceive initiatives proposed by the public administrations.

When asked about what he knows about the climate goals proposed by the Danish government, Jens replies:

*"I know the basics of it, but I have not really looked into it. I am pessimistic regarding the transition from fossil fuels to something greener. I think it is crazy to have these gross taxes on what is common sense. Especially the thing about solar panels and its taxes"* (Appendix 8, p. 25)

Mikkel also has an opinion about this. When asked about why he thinks other people are not interested in energy renovations, Mikkel tells us:

*"The prices and the loans for it, as well as the inconvenience about it. There was also something about the rules if you had solar panels. They were changes, so it was no longer as profitable to those who had solar panels"*

The interviewer*: So, it is something about distrust in the system?*

Mikkel continues*: "I understand why people are not willing to do it anymore"* (Appendix 8, p. 45)

To the same question, Nichlas, who has invested in solar panels, replies:

*"They probably will, if it is profitable. The investment has to turn out into lower energy consumption. These solar panels I installed… I can save some money, but not much. They have been there for 9 years now. The first 6 months it was a good business. But now you pay all sorts of taxes. Theoretically, I should not pay anything for electricity, but the costs of being self-providing is 8.700 DKK per year".*

*The interviewer: "So it was only profitable for 6 months?"*

*Nichlas continues: "Yes, it was only profitable in that period. Since then, it has become more and more expensive"* (Appendix 8, p. 50).

On a more local level, in 2012 the municipality of Høje Taastrup initiated a project that was supposed to implement district heating in Fløng. A project that, as described in chapter 1.7 The project failed for different reasons. Partly because of the initially promised economical prospect for the house owners, which turned out to be very different from what the house owners could actually expect.

Carsten talks about this issue:

*"The municipality of Høje Taastrup made some different actions and have basically put district heating into the most. Just apart from the civic association I am a member of. Because there was a big consultancy company, which had miscalculated and provided the wrong prices, so it was actually more expensive than they had anticipated. Then we said to the mayor, who by the way is my party comrade: Michael, this does not work damnit, it is getting more expensive than what we already have. So, that is the reason we did not get district heating here, and hopefully never will"* (Appendix 8, p. 33)

Hans also addresses this issue, when talking about being self-providing (more on this topic later):

*"Regarding district heating, I will at any time go around it, because there have been so many cases where they (the public administrations) has not been able to manage it on behalf of the citizens, which means it has been more expensive to the citizens compared to the heat supply they had before. This is a terror example of how it can be done. Because the energy source, if it is produced from the surplus heat, can be fantastic, but then you read a newspaper article about one being taxed from the surplus heat. Here I believe there is a lot of bureaucracy that needs to be figured out before one gets the good solutions"* (Appendix 8, p. 20)

Previous cases and projects, like the above-mentioned solar panel case and the district heating project in Fløng, where house owners have felt deceived by the public administrations have, within the house owners, manifested in some degree of distrust in the public administrations when it comes to projects or initiatives proposed by either the government or the municipality.

## Obligatory Collective Solution or The Freedom of Owning the Solution

As mentioned earlier in this chapter, the most socio-economical heat supply solution, through the lens of the heat supply legislation, is often district heating. For the house owners, district heating often comes with one or two obligations, as described in chapter 5. One of the obligations is a mandatory connection. The mandatory obligation is a tool, that can be applied by the municipality and can enforce the collective supply source onto the residents in a certain area. In practice though, the mandatory obligation is not always being applied, if there is a strong resistance against it in the inflicted community, as in the case of Fløng. The other obligation is the commitment obligation. This obligation can be imposed to house owners who voluntarily connect their house to the collective supply source. If the commitment obligation is imposed, the house owner is obligated to commit to the collective supply source. There are some exceptions to the mandatory connection and the commitment obligation. For example, if the concerned building has renewable energy facilitation, including solar panels, heat pumps, biogas facility and more.

These obligations are of some concern to the house owners, who do not like to be bound to one solution.

Carsten says, when being asked if he has considered more renovations to his house:

*"It is difficult to do more on a house like mine. But at some time, my oil-fired boiler will give up. (…) Then it is almost entirely certain, that it will be replaced with an air to water heat pump, so that I still have my own energy facility"* (Appendix 8, p 36)

When asked about which heat supply there is in his new house, Hans replies:

*"That is natural gas, but I have never tried to work with that before and have not had natural gas before. (…) I have considered if it in the future can be profitable with an air to water heat pump. I believe that natural gas is a source that at some time go extinct. And being able to produce heat on your own property, you know, producing electricity and such, I can see there is a future in that"* (Appendix 8, p. 18).

Later in the interview, Hans is being asked to relate to the prospect of Denmark being fossil-free in 2050. He then returns to the above:

*"At first, I have to try to have it (natural gas), but I believe that I within a foreseeable timeframe have replaced it with an air to water heat pump. Also, because the new roof is made in a way that it is possible to install solar panels on it. And if I can generate the power to heating. I have not studied it that much, but some manufacturers talk about having a battery, to which the solar panels can store electricity during the day and then use it during the night. (…) When we reach a point, where that becomes a feasible solution, because right now it is very expensive, the way the batteries are made. One thing Is, that they collapse in the cells after some time and they do not last as long one would like. This we know from our phone battery. After a while, they got tired and the efficiency drops. Knowing that my primary energy source dies within 10 years, then I believe it will be a*

*relatively expensive solution, also for the environment, if the battery all the time has to be replaced. But I am excited about what the future brings regarding smarter solutions. But I look at alternatives to the natural gas because I would like to be self-providing"* (Appendix 8, p. 20).

The house owners express a wish to have ownership over their own energy supply so that they can also control how their house is provided with energy and be able to adapt to the changes that might happen. This attitude is in conflict with the obligations that often comes with connecting to the collective supply source.

## Inconveniences When Connecting to the District Heating Grid

Another obstacle for the success of a municipal supply source project, as described by the house owners in Fløng, is the infrastructure of the supply sources. As described in chapter 5 Fløng is a town where most of the residents have natural gas as the primary supply source. This means, that the gas grid in Fløng is fully implemented, whereas the district heating grid in Fløng is almost not existing. This means, that it is very convenient for the house owners in Fløng to stay committed to natural gas as the primary supply source. If the house owners are to replace natural gas with district heating, there are some inconveniences connected to this replacement.

When asked about if a collective solution in the neighborhood could be beneficial, Carsten replies:

*"No, because if you want to do something like that, you need to make something that is on a grid. That will look a lot like district heating. Then someone must supervise it, there must be excavated and the shit rusts. I do not believe in that"* (Appendix 8, p. 40).

Hans talks about the municipal district heating project and tells us:

*"I know, at least, that there in 2011 was held a meeting regarding how it was possible to optimize the houses and they talked about installing district heating in the respective residences. And that ended in a lot of commotion. The thing about you had to rebuild the whole house to use the heat supply. The thing about using 150.000 DKK on something that potentially will cost more money. There was not any great support to that"* (Appendix 8, p. 16).

Mikkel, who installed a new natural gas furnace in 2010 is asked if he had other solutions in mind back then. Mikkel answers:

*"No, we did not. There is already gas, so we just had to replace it. If you want something put down, you need to dig up the driveway and the garden, so that is not feasible"* (Appendix 8, p. 46).

The one-time fee for connecting the house to the district heating grid as well as the inconvenience connected to the installation in form of digging up parts of the property is a big obstacle for the house owners to convert to district heating. It is simply too convenient to stay with what they already have.

## The Definition of the Obligatory Passage Point

In the above, the actors that are central to a municipal project to reduce greenhouse gas emissions in the town of Fløng. Also, the interrelation between the actors has been identified through the obstacles that prevent the success of the overall goal of implementing more sustainable solutions, thus reducing the greenhouse gas emission from single-family homes in Fløng. The actors identified above, each has their own agenda and their own goal they would like to obtain.

The heat supply legislation has an admirable goal of being both socio-economically and environmentally profitable but often fails in practice because of the resistance from another actor; the house owner.

The house owner also has his or her own agenda. Although recognizing the need to reduce greenhouse gas emissions in order to deal with the current climate crisis, the house owner is not willing to lose money. If the house owner is willing to lose money, it is only within a short timeframe and the money needs to be returned in savings.

The public administrations, here the Danish government and the municipality of Høje Taastrup, have already tried to implement greenhouse gas reducing actions. But as described above these actions, because of the process, have turned out to some degree of distrust in the public administrations. A distrust that now manifests as resistance within the network, preventing the public administrations in reaching the overall goal of reducing greenhouse gas emissions.

The supply sources are a bit trickier when it comes to having an agenda of reducing greenhouse gas emission. The older solutions like oil- or gas-fired boilers are emitting quite substantial amounts of greenhouse gasses, but since the aim in the first place is to replace these technologies with more modern and more sustainable technologies, let us focus on those technologies. The sustainable technologies want to reduce greenhouse gas emissions, by replacing the older technologies that are already in the houses in Fløng. When it comes to the municipal projects though, as already described, the technology is more often than not a collective solution. The collective solutions seem to fail, because of the resistance met by the house owners, that do not like the prospect of being obligated to be connected to the collective solution. The house owners prefer ownership of the supply technology.

Lastly, the district heating grid wants to reduce greenhouse gas emissions, by connecting itself to the houses in Fløng. The problem is that the houses in Fløng is already connected to another grid. The gas grid. This creates some resistance from the house owners, who do not want to take on the investment and the inconvenience connected to installing the district heating grid in their house.

To overcome the resistance within the network, thus being successful in reaching the individual goals, they must start to form alliances and begin to aim for a common goal. This goal is the *obligatory passage point.* The point through which all the actors are connected and must go through, to obtain their individual goal. The common denominator, in this case, is the house owners. The house owners are the ones making the decision to take action on making sustainable solutions in their houses. Thus, the actors need to answer the question: How is the house owner motivated to take action on implementing sustainable solutions in their house?

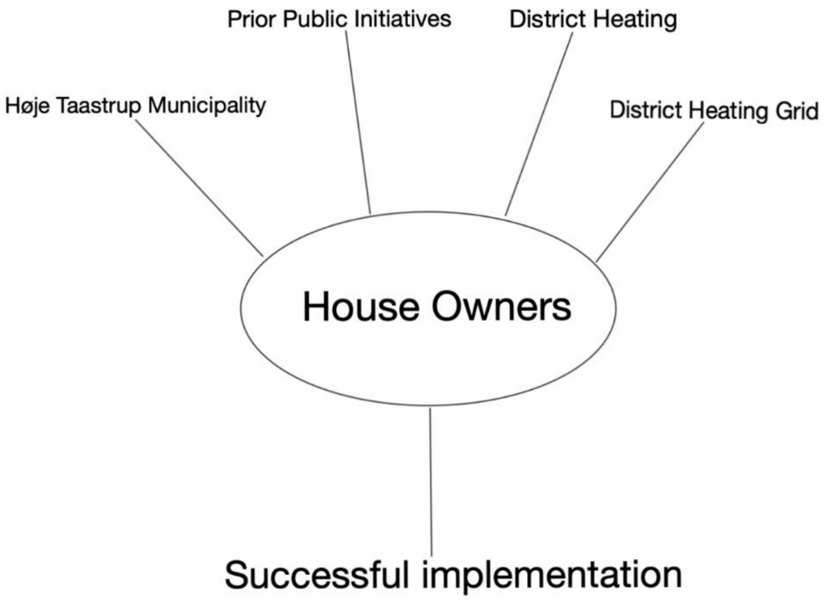



*Illustration of Obligatory Passage Point*

## 8.3 Interessement

Now that the actors and the interrelations between the actors have been identified through the obstacles that prevent them from reaching their individual goals, and the *obligatory passage point* has been established, it is time to determine how the actors can reach the new common goal. From an actor-network perspective, this is done by identifying entities, that can be placed in between the actors, ensuring that the actors do not work against the common goal. To ensure this, the entities that are placed in between the actors are supposed to cut off the reason or reasons why the actor moves away from the common goal.

### The Legislation – Prone to Favor District Heating

The easy answer to how the municipality can get around the heat supply legislation, would be to simply change the legislation or ultimately abolish it. This solution though, is not very likely to work in practice, since the municipality has no authority to make legislative changes. Instead, the study proposes to introduce an entity to the network, that ensures that alternative projects can be socio-economically profitable as well. By ensuring that other projects than district heating can be socio-economically profitable, the heat supply legislation does not get pulled away from the common goal in the actor-network, but instead it starts to working together with the other actors towards the common goal of motivating the house owners to implement sustainable solutions to their residence. Since it is not possible for most of the solutions to produce electricity, or any other product, to be sold, thus creating an income as district heating does, the income must be generated in another way. This could be by letting local businesses handle the sales and the installation of the sustainable solutions. Thus, the economy is kept within the municipality ensuring jobs and tax income.

## The House Owner – Wants Small Investments and Quick Profit

To the house owners, the absolutely biggest obstacle for taking sustainable actions on their residences is the economy. The one-time investment and the prospect of not being able to make a profit off of that investment in a foreseeable future, drives the house owners to take actions that do not benefit the common goal in the actor-network. To get the house owners to take actions that benefit the common goal instead of going against it, an entity must be introduced, that cuts off the reason the house owners to go against the common goal. Since the main reason behind the house owners not investing in sustainable solutions, is the prize, the easy answer is to lower the prizes. Most of the solutions do come with a cost though. To lower the costs, the municipality can offer a financial subsidy to house owners that choose to make sustainable investments in their residences. This may be the help some house owners are looking for, while other house owners still find the price too high. E.g. if the solutions cost 100.000 DKK and the subsidy is 20.000 DKK. To those individuals, it may be beneficial to be introduced to a solution that requires a much smaller investment. This solution is already available. As described in chapter 5 the air to air heat pump can be purchased and installed at a very low cost and it is very energy efficient, thus the investment is quickly profitable. The house owners simply need to be informed of this solution. Thus, an entity to introduce to the network could be information about the possible solutions.

## The Public Administrations – Prior Actions have caused Distrust

When it comes to actions from or solutions provided by the municipality, the citizens tend to have some degree of distrust in the public administration. This often, as described earlier, comes from former projects where the citizens have felt deceived by the public administrations. The problem here is, that it is not possible to remove those unfortunate cases that led to the distrust. Instead, the trust must be reestablished. The best way to re-establish trust is for the public administrations to perpetually make successful projects in favor of the citizens. This takes a long time though, a time we do not have. Instead, the study proposes that the municipality go out and meet the house owners where they are, at the house owners' turf. A way to do this is to facilitate a series of workshops, where the house owners are invited to give their view on the subject and to have a dialogue with the municipality. Also, the municipality should strive to provide transparent information about the project and possible solutions to the house owners.

## Ownership

As identified in the *problematization* section, an obstacle for a municipal heat supply project is that the house owners prefer ownership of their solution as opposed to committing to a collective solution as district heating. Although natural gas is a collective solution as well, the house owners are not committed to that solution. The house owners are free to replace the natural gas boiler with whatever solution they would like. Of cause, it is also possible to replace district heating with another solution, but If there is a commitment obligation connected to the district heating, the house owner is obligated to pay the annual fee, regardless of which heat supply is actually in use. There are two ways to accommodate this issue. One is to remove the obligations, and another is to provide solutions that are either free of obligations or fully owned by the house owners. Removing the obligations will weaken the resistance from the house owners towards district heating, thus strengthen the connection in the network between the house owners and district heating. Providing a solution that is fully owned by the house owners, on the other hand, will strengthen the connection between the house owners and the non-collective solutions, thus weakening the connection between the house owners and district heating.

## The Grids – Gas and (Almost) No District Heating

Another obstacle identified in the *problematization* section is the grids available or the grids connected to houses in Fløng. In Fløng, most houses are connected to the gas grid, but not the district heating grid. Meaning that any house owner, that wishes to install district heating in their house must accept that both or either the driveway or the garden needs to undergo some digging. Now, it would be perfect if it was possible to go around this digging, but if a house owner wishes to install district heating, the house owner must accept this digging. Another obstacle for the house owners to connect to the district heating grid is the prize. It is quite costly for a house owner to connect to the district heating grid; thus, many house owners choose other solutions or not to replace their current solution at all. If it in some way is possible to reduce the costs of connecting to the district heating grid, this would weaken the resistance and strengthen the connection in the network between the house owners and the district heating grid. As for the gas grid, the connection between the gas grid and the house owners are already quite strong, as most of the houses in Fløng are connected to the gas grid, not only in the perspective of ANT but also physically. The connection between the gas grid and the sustainable solutions, on the other hand, is weakening as the natural gas is being phased out. This means, that if the house owners in Fløng do not make the transition from natural gas to district heating, in time there will be almost no houses in Fløng connected to the collective heat supply. Even though natural as is being phased out, the grid remains. As described in chapter 5 the gas grid does not only distribute the fossil-based natural gas. It also distributes sustainable biogas. Thus, the connection between the houses in Fløng and the sustainable solutions can be strengthened by adding more biogas into the gas grid and in time replace natural gas entirely.

## Summary

This *interessement* section has tried to identify those factors that can weaken the link between the actors and their individual goals that creates resistance in the network. While weakening the link that creates resistance the connections between the actors that makes them move towards the common goal, or the *obligatory passage point*, is strengthened. As described above what strengthens the connections in the network toward one solution, may weaken the connections towards another solution. E.g. if the connections in the network between the house owners and the fully owned solutions are strengthened, the connections between the house owners and the collective solution is weakened. This may seem counter-intuitive, but either way, the connections in the network that moves towards the common goal of motivating the house owners to take sustainable actions on their residences are strengthened. Furthermore, this ensures less resistance in the network against all available sustainable solutions as well as strengthening the connections between the house owners and whatever sustainable solution fits them the best.

Now, let us put the suggestions above into a common solution. A solution that cuts off or weakens the connections pulling the actors in the direction of their individual goals while strengthening the connections that pull the actors towards the common goal of motivating the house owners to take sustainable actions on their residences. Firstly, the municipality should keep launching district heating projects. District heating is a sustainable solution that can be favored by some house owners. To strengthen the connections in the network between the house owners and district heating, the obligations that are often included in a district heating project should be waivered. In addition to this, the municipality should facilitate workshops in Fløng, where they can meet the house owners and have a dialogue about what the house owners wish from the municipality as well as what the municipality is actually capable of doing. This makes the municipality more visible to the house owners and helps to reestablish trust in the municipality, thus strengthening the connections in the network between the house owners and the municipality. When launching a district heating project, the municipality should also make an effort to negotiate advantageous discounts on behalf of the house owners in order to lower the installation price, making the solution more appealing to the house owners. If possible, the municipality can even provide some financial subsidies to promote the replacement of the current non-sustainable solutions in Fløng single-family houses. This subsidy can also be applied to other projects than a district heating project. In these projects, for example, heat pump projects, the municipality should make an effort to negotiate favorable deals on behalf of the house owners with the local businesses that sell and installs heat pumps. Thus, the house owners can purchase the desired heat pump at a lower cost and the municipality keeps the economy within the municipality, ensuring local jobs and tax income. Lastly, the municipality should look into the prospect of adding more biogas into the gas grid and eventually replace it altogether. This way, the gas grid can still be used for a sustainable solution instead of just being left in the ground. As the biogas expert told in the interview for this study, the potential amount of biogas in Denmark is just about equivalent to the amount of natural gas being used in Denmark today. In time, new houses are being built and current houses are getting renovated, the demand for gas will drop. This may not be enough, since biogas today also is intended for a role within transportation. Instead, a hybrid solution can be suggested. Due to the

Danish building regulation legislation, an air to air heat pump cannot be the primary heat source in a residence. Also, the air to air heat pump is not able to heat domestic water, thus a house with an air to air heat pump needs an additional supply source to heat domestic water. A solution to this could be a hybrid between a 100% biogas connection, supplemented by an air to air heat pump. The gas grid will not be able to fully contain biogas for some years to come, but until then, the air to air heat pump can be a supplement to the current gas boiler, thus reducing the greenhouse gas emission substantially right away at a low first-time fee and a quick repay rate. Of cause, this solution is only profitable to those who is connected to the gas grid. That is why the municipality should do all the above, so that they also make sure, that the connections in the network that motivates the house owners to make sustainable solutions on their residence are strengthened and not resisting the common goal.

## 8.4 Enrollment

So far in this chapter, the obstacles for a successful municipal source supply project have been

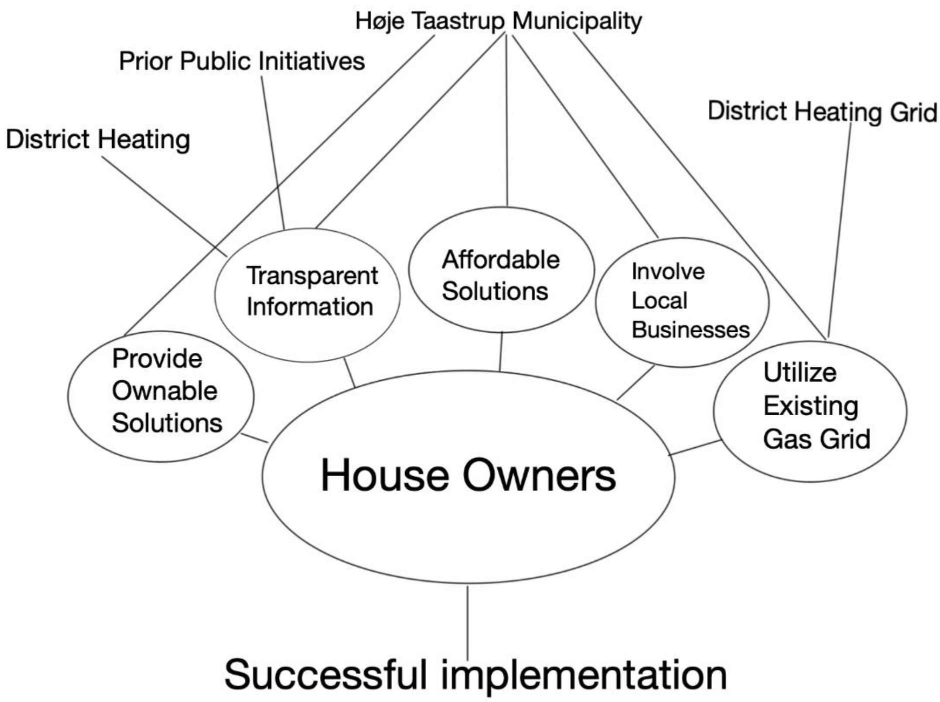



*Illustration of interessements between the actors*

identified as well as the entities that can cut off the factors that induce resistance in the network. So, now all should be good, and the network is stable? Well, as described in chapter 6, an actor-network is a dynamic organism, where the actors constantly try to break off on their own. To ensure this will not happen and the alliances forged in *interessement* is perpetuated, the actors must undergo a series of negotiations with each other, in order to define their roles in the network. Or in other words, how the actors can enroll the *interessements* described above.

## The Municipality

First of all, the role of the municipality is to be visible to the rest of the actors in the network. Especially the house owners.

In the interview Torben tells us:

*"I believe the municipality of Høje Taastrup does an okay job. On the institutions – we have a school op here – they have established solar panels in a wide extend. I believe it should cover the school's needs. They do the same at the nurseries and the kindergartens in the area. In the city hall they have also put up solar panels with one of those kWh counters, so one can see if it is a good or a bad business. So, they do an okay job"* (Appendix 8, p. 54)

This statement shows how Torben acknowledge the municipality's contribution and work through the visibility of the actions made by the municipality. If it had not been visible to Torben, he may not have known about the good work done by the municipality.

While being more visible, the role of the municipality is also to provide information to the house owners. As already mentioned, the house owners want to invest as little as possible and profit off of the investment as soon as possible. Thus, the municipality must provide the house owners with sufficient information about prices as consumption of the different solutions, helping the house owners to decide which solutions fit them the best. Also, the municipality must provide information about how much greenhouse gasses the different solutions emits. One of the informants in this study, Daniella, is very interested in making sustainable changes and is also willing to pay extra in order to do so. Daniella's current supply source is natural gas. Daniella is asked how much she knows about natural gas. The conversation goes:

*Daniella: "If it is messy or not?"*

*Interviewer: "yes"*

*Daniella: "Now, I do not actually know that. Is natural gas not good? I thought it was good"* (Appendix 8, p. 10)

This shows, that even with the best intentions, the house owners still need to be provided with sufficient information to make the decisions they actually want to make. In this case, Daniella wants to make sustainable decisions, but due to a lack of information, she ends up not making any decision regarding her supply source.

Lastly, the role of the municipality is to negotiate favorable deals on behalf of the house owners regarding sustainable solutions. This does not necessarily have to be an actual negotiation where the municipality signs a deal with the local businesses. It can merely be the municipality informing the local businesses about the prospect of a lot of sustainable sales, thus letting the market lower the prices on its own.

Overall, if the municipality takes on the role of a link between the actors and provides sufficient information, the municipality helps to reinforce the connections within the network and to ensure the above-mentioned *interessements*.

## The Experts

In this section, technological solutions will be represented by experts in the field. The role of the experts, in order to ensure that the new alliances in the network will be successful, is to provide transparent and coherent information about the field.

As described earlier, the biogas expert interviewed for this study, has informed that the potential for biogas in Denmark, is almost equivalent to the contemporary gas consumption. An expert on another technology meanwhile informed this study, that it is not possible to produce those amounts of biogas.

Also, Carsten expresses his opinion on district heating:

*"If you look at the government intend to do. They will get rid of fossil fuels, which means oil and gas must go. Then there are all those *bad sound* sorry for the expression, who say, then we must get district heating. It is cheap and it pollutes very little. Well, they do not learn about the stuff, do they? It is not cheap; it is tax-free. That is why the price is lower. The amount of $CO_2$ when using biofuels is at least as high as when you use oil or coal for that matter. So, I am not having any of those"* (Appendix 8, p. 40).

This statement shows how the knowledge about the field within the public and between the experts is not coherent. Thus, the experts need to take on the role to provide the public with precise and coherent information, so that the house owners can feel certain that they make a decision based on the correct information, instead of being confused about conflicting information.

Palle also talks about this:

*"It demands a consensus from the experts, so that they don't come and tell something different. Because I have been told. I look at my energy report and it says. Well, when we bought the house,*

*it's energy labeled B. Well, by installing solar panels you can save 0,56 tons $CO_2$ a year it said. Recommended by the energy experts, right?. Certified, stamped, and everything. Installation of heat pump – Potential of $CO_2$ savings a year: 110 kg – 0,11 tons. Well, that was not quite true, that was actually 1,3 (Palles actual savings from his heat pump). As long as they contradict you, then there is nothing. Then they will say. That's not how it is. Look, I got my energy report. It says it right here. It's an expert. Then this fancy guy comes and says it is possible. Well, it is, because I have taken pictures of my electricity meter. I've talked to my gas company. I've looked at how much electricity those living here before used"* (Appendix 8, p. 67).

This shows that the experts making the energy reports and the calculations on which many house owners base their choice upon are not correct every time. This is very clear when Palle has been able to save almost 1,2 ton more $CO_2$ than the experts had calculated.

## The House Owners

The key to all of the above is the house owners. Nothing happens if the house owners choose not to take any action. The easy answer is then that the house owners' role is to engage in the project and make sustainable changes to their residences. While that obviously is an important part of a common goal, it is also important, that the house owners take on the role of spreading the good word. In the interview with Daniella, when asked about if people in Fløng talk about sustainability, she replies:

*"Nah, I really don't believe they do. I really don't believe they do. There are a lot, that may not think about it that much"* (Appendix 8, 4).

Nichlas also talks about this, when asked about how the topics of sustainability and climate have developed in Fløng:

*"I have only lived here for 9 years, so I don't know how other people act regarding their energy consumption. It is a bit difficult to know as a private person. I think that packing, plastic and so on can be seen in the daily living. There you can see something happening.*

*These statements show, that the citizens in Fløng do not talk much about sustainability with one another, and especially not when it comes to private energy consumption.*

*When asked about what could make a difference, Palle, who has saved both money and greenhouse gas emission on his heat pump, answers:*

*"Show some examples, but that's not enough. Now, take guys like me. We could tell about what we have done. I have showed it to some friends and told them, that here we can save some $CO_2$ and we can also save some money. We save a couple of thousands each year. They only pay 10.000 a year for gas, I don't even wanna touch that they say. They are not even interested, and you cannot make them do it. You can save 2000 I tell them. Well, and? It's inconvenient. No, it has to do with citizenship and it's all about talking it up, right?. But it will be something about talking it up and explain how it is"* (Appendix 8, p. 67).

This shows that it is not enough just telling people that they can save some money. To really ensure the *interessement*, the house owners in Fløng must start to talk to each other about the good stories, thus spreading the word about successful stories, where they have saved both money and greenhouse gas emission. The current discourse must be changed.

## 8.5 Mobilization

Now that the following moments have been completed:

1) The actors have been identified along with the obstacles that drives them away from the common goal

2) A set of entities to weaken the connections that drives the actors away from the common goal and strengthens the connections that drive them towards the common goal have been established.

3) The actors have been allocated roles in order to perpetuate the connections that drives the actors towards the common goal.

All that is left, is to determine how the allocated roles are mobilized.

## The Municipality

Previously it has been established which role the municipality should take, in order to ensure the success of *interessement*. But the municipality is an enormous organ with lots of different departments. And to expect the mayor himself will engage in the project may be slightly too ambitious. Instead, the municipality must be represented by someone or something that can take on the allocated role and will dedicate their work to the common goal in the network. The municipality already has a department allocated to work with projects like this. The department of environment, by which the authors of this study initially was introduced to the issue of implementing sustainable solutions within single-family houses in the municipality of Høje Taastrup. Through the environmental department, the authors of this study have established contact with both some experts and some house owners. Thus, the environmental department, besides the obvious fact that they already work within the field, already have contacts with both experts and house owners. This makes the environmental department the obvious spokesperson for the municipality.

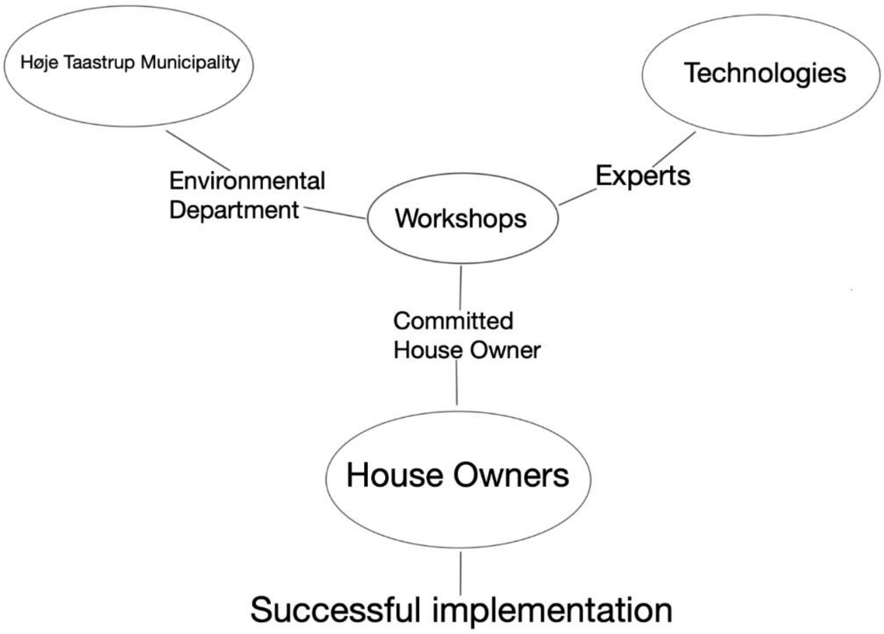
## The Experts

As mentioned in the previous section, the technologies should be represented by some experts. Experts that will communicate and provide transparent and coherent information to both the municipality and the house owners. Thus, making the choices for both the municipality and the house owners easier to make and so that they feel their choices are made on a sound foundation. As described above, the experts present incoherent, contradictory and inconclusive information. For this reason, this study recommends that a technology board is established, and each technology should be represented by an expert. This way, the experts will discuss the implementation of the technologies affects the individual house owner’s economy as well as the house owner’s greenhouse gas emission.

## The House Owners

To expect that the house owners start to share the good stories and spread the words on their own may be to expect too much. Of cause, if the good stories find their way to the house owners, there is a chance that the stories will spread automatically within the community. Though this may happen, this study will nonetheless suggest that the house owners mobilize certain spokespersons, who will be the main drivers of spreading the good stories within the community. As already explained, this can very well be a person like Palle, who have installed an air to air heat pump as a supplement to natural gas. Now, Palle only uses natural gas for heating domestic water, thus reducing his $CO_2$ emission by 1,3 tons a year (Appendix 8, p. 63). As Palle mentions in the statement above, his energy report said that he could only save 0,11 tons. Mobilizing Palle as a spokesperson for that particular solution – the heat pump-gas hybrid – can wake the interest of more house owners to look into that solution. As mentioned earlier, not one solution fits all houses or house owners, so preferably there should be a spokesperson for every good story about each solution.

By mobilizing these spokespersons, the municipality will stay in close contact with the house owners, thus reestablishing trust in the system and the house owner know who to contact and where to seek information. Information that will now be coherent and give the house owners a sound foundation to make a decision upon. The house owners will also know about the good solutions and the positive effect hereof because they share and spread the good stories within the community.




*The interplay between the spokesmen*

## 8.6 Alignment

To end the analysis of translation processes and *The Four Moments of Translation* the term *alignment* will be used to comprehend if the network in Fløng can sustain itself and how the future perspective on the network could be for energy renovation and heating supply in Fløng.

Through the generated data and actor-network theory is it clear that the network in Høje Taastrup municipality regarding energy renovation and heat supply in Fløng is unstable. There is no *alignment* in the network which occurs from different opinions from the actors of the network. The difference in opinion from the citizens and the municipality is fundamental for the instability in the network. Additionally, the network is missing a key stakeholder, which is a spokesman from both parts. The spokesmen could create a stronger interplay between the municipality and the citizens, especially in terms of reaching the common goal. It is clear that the network is unstable through previous projects in Fløng with district heating. Here the project ended unsuccessfully, because of the lack of communication. The lack of *alignment* in the network could be created through negotiations from both parts towards a common goal, but with the current direction of the network could it seem to be unstable in the future too.

*The Four Moments of Translation* has illuminated the missing parts in the network and clarified areas, which could be improved towards a more stable network. Including the lack of communication and the economical parts as key topics that need to be aligned between the municipality and the citizens towards the goal of energy reduction in single-family houses.

The missing *alignment* can be clarified through the former example of district heating in Fløng, where there was not any beneficial element in the direction of the citizens, which indicates the difference of opinions regarding the common goal. The lack of communication and *alignment* can be noticed in the following citation from Palle:

*"It demands a consensus from the experts, so that they don't come and tell something different. Because I have been told. I look at my energy report and it says. Well, when we bought the house, it's energy labeled B. Well, by installing solar panels you can save 0,56 tons $CO_2$ a year it said. Recommended by the energy experts, right?. Certified, stamped and everything. Installation of heat pump – Potential of $CO_2$ savings a year: 110 kg – 0,11 tons. Well, that was not quite true, that was actually 1,3 (Palles actual savings from his heat pump). As long as they contradict you, then there is nothing. Then they will say. That's not how it is. Look, I got my energy report. It says it right here. It's an expert. Then this fancy guy comes and says it is possible. Well, it is, because I have taken pictures of my electricity meter. I've talked to my gas company. I've looked at how much electricity those living here before used"* (Appendix 8, p. 67).

The citation illuminates the lacking *alignment* in the network which clarifies the instability of the network, which could end with not reaching the common goal for the municipality and citizens.

# 9.0 Discussion

This discussion will be about the climate action plan in relation to Fløng be presented. Furthermore, a discussion of the distrust among users regarding previous project will be illuminated. At last, a discussion of how Critical Theory of Technology could have been used in this project will be described.

## 9.1 Climate Action Plan

This section of the discussion of the newly proposed climate action plan from the Danish government will be discussed in relation to energy renovation and heat supply.

The climate debate is running at full speed right now in Denmark. The Danish government has set an ambitious goal of reducing greenhouse gas emissions by 70 % by 2030, which means that actions must be taken now to achieve the ambitious goal by 2030. Denmark has always been a frontrunner in green technologies and is known for windmills, and especially windmills will have a huge role to play in terms of reaching the goal of reducing greenhouse gas emissions by 2030.

On the 20th of May 2020, the Danish government presented its first climate action plan, which will be a part of the 2030 goal, but also the 2050 goal of becoming climate neutral.

The climate action plan, that was presented by the Danish government consists of six actions that will contribute to reducing greenhouse gas emission, which is crucial if the 2030 goal must be achieved. The six actions that the government presented are the following:

1. Energy Islands
2. Investment in Technology
3. Green Transition of the Danish Industry
4. Energy Efficiency of Buildings and Industry
5. Phasing out Oil and Natural Gas
6. Climate-neutral waste sector by 2030.

How will these actions affect the house owners in Fløng?

The government of Denmark, has in the climate action plan made it clear that oil and natural gas-based heat supplies are being phased out, the reason why is because the government wants a green heat supply sector in Denmark, and as oil and natural gas are fossil fuels the government are taking action by phasing out natural gas and oil, and instead use green district heat or electrical heat pumps.

As mentioned earlier in this report, most of the single-family houses in Fløng have a primary heat supply based on natural gas or liquid fuel, which indicates that the new government’s climate action plan will directly affect house owners in Fløng. The new climate action plan indicates that house owners in Fløng that have a heat supply based on oil or natural gas must either switch to heat pumps or join district heating. How does the new climate action plan comply with what our informants have expressed during the interviews?

In 2012 a municipal project regarding implementation of district heating in Fløng was initiated, however, things did not go as the municipality had anticipated, because there was not a consensus among house owners in Fløng to join district heating, due to many factors. According to several of our informants, the price changed during the project and there was a requirement of being bound to district heating, which was not welcomed by house owners in Fløng.

The house owners in Fløng could not justify joining district heating as the price was unclear and the fact that they were forced to be a part of the district heating meant that the interest in district heating quickly disappeared. Furthermore, the oil prices and gas prices were low, which also did not help the district heating project. Additionally, the district heating project meant that the house owners had to dismantle their old solution if they wanted to join district heating, which in most cases were natural gas furnaces/kettles and oil furnaces/kettles which meant that their investment had to be dismantled and scrapped. It was simply not worth the trouble. The district heating project in 2012 meant that only the western part of Fløng joined district heating, while the rest of Fløng did not and continued with their current solutions.

If the municipality of Høje Taastrup did not succeed in implementing district heat back in 2012, then what will the house owners do in relation to the new climate action plan?

The consensus of our informants was that most of them wanted their own heat supply solution, which means that they want to own their own heat supply. The fact that house owners in Fløng eagers after owning their own solution, makes it hard to believe that they will join district heating in the coming years, unless they can see economic benefits by joining a collective solution.

The government's climate action plan suggests either district heating or electrical heat pumps as a replacement for fossil fuels. Based on our informants and their eager to own their own heat supply solution, heat pumps could be a good solution. The government suggests two options in terms of heat pumps, a subscription solution where the pump is rented by a utility company, which keeps the investment cost low. The second solution is to buy the heat pump thus having ownership over the heat supply.

In the new climate action plan, the government gives the opportunity for building owners to receive increased economical grants and tax deductions, which the government hopes will help motivate building owners to takes action and replace their "black" solution with a green one.

The increased grants and deductions can be a valuable actor in motivating house owners in Fløng. Furthermore, the municipality of Høje Taastrup can provide consultancy in relation to choosing the right solution whatever if it is in terms of heat supply or energy renovation.

The increased grants and deductions will, especially be valuable in terms of energy renovation, as more house owners can be motivated due to the economical help, which will help justify a renovation project and all the inconveniences that are connected to a renovation.

There must be economical benefits for the house owners before they bother with the hassle of energy renovation or replacement of their heat supply. The investment of the house owners, preferable must be repaid within a foreseeable timeframe. In relation to the new climate action plan, the argument is that the house owners in Fløng will probably replace their oil or natural gas solutions with, in most cases, heat pumps that they can either rent or own themselves.

Although natural gas is a collective form of heat supply, our informants perceive it as an individual solution, this could be because they themselves buy the gas furnaces and kettles and it is visible in the house. The fact that the heat is produced by the furnaces and kettle in the house can be why our informants perceive natural gas heat supply as their own.

However, the climate action plan does not mention biogas as a replacement gas for natural gas, which is strange as the gas grid today, contains a smaller percentage of biogas. According to our expert from EVIDA, the future of the gas grid is based on biogas, but it is not mentioned as a solution in the climate action plan, which indicates that the government does not see biogas as an alternative gas to natural gas.

## 9.2 Distrust

This part of the discussion consists of the topic of distrust in public authorities and aims to inspect and discuss what influences the changes in duties from solar cell panels have for future similar projects and how this change could affect the inhabitants' trust in the public sector.

As mentioned earlier in the report there has been a change in duties from the public administration. In 2012 into early 2013 the public administration changed the duties, which ended with countless discontented solar cell owners. The action of the changed duties has hence created a degree of distrust towards the public administration and therefore it could be significant to look at the question of how does mistrust affects current and upcoming projects?

The main issue with distrust is that it is something that can be rebuild, but it takes time to obtain the same level of trust again. This is also expressed with the decrease in the sale of solar cell panels after the change in duties. Furthermore, distrust has created a level of skepticism towards other projects which is similar to solar cell panels. For this reason, people might be more careful about where to invest their money since there could be a change of direction from the public administration similar to the project with solar cell panels. The interplay between public administration and inhabitants regarding greenhouse gas-friendly projects is fundamental for future projects on topic. It is important to look at the public administration's perspective on this topic, which could make it more understandable for citizens. This could for instance be that the public administration did not consider that there would be so much interest in the project as there were back then. Therefore, they were forced to change the duties, especially if the investments in solar cell panels could cause overproduction on the electricity network. Furthermore, the overproduction in the electricity network the public administration was forced to change the duties because of the income the owners could get from the investment of solar cell panels and how it negatively could affect the public purse.

The issue of distrust from inhabitants towards the public administration was also visible in Fløng, where they established district heating. Here the house owners in Fløng could not justify joining district heating as the price was unclear, especially because they were forced to be a part of the district heating in a specified time interval. Furthermore, the oil and gas prices were low at the time. In addition to this, citizens were skeptical for new initiatives because of the change of duties in solar cell panels and the distrust there has been built through that change. Therefore, the initiative from the municipality did not go as expected, because it was simply not worth the trouble for the citizens in Fløng. Because of unsuccessful initiatives and changes in duties, it is important to illuminate and discuss how the public administrations can recreate the trust between them and house owners again regarding energy-friendly solutions similar to solar cell panels. How can the public administrations recreate the trust between them and the citizens? The problem with trust, and especially wrecked trust, is that it takes time for the opposite side to regain the same level of trust again. One of the main elements which could be discussed is transparency from the public administration. Here they could through workshops and information meetings meet the citizens on eye level, whereupon they could create a clearer way to communicate with the citizens. The transparency from the public administrations could remove uncertainty from the citizens.

Workshops could be a significant design method to understand the citizens and create a platform where the citizens sense that they are being heard. This is apparent in the project of district heating in Fløng where it is clear that there has not been enough interplay with the citizens and especially house owners. Workshops could create an understanding of the house owners and what is needed for them. Through the generated data from this report it is clear that the citizens need more information on upcoming projects, and with a mix of mistrust in the back of the minds of citizens and lack of information could the projects end as unsuccessful. It is necessary for the public administration that the citizens show engagement and participate in workshops, especially if the citizens want to be heard. The element of information could be discussed from both parts, for the reason, that information is available from the public administrations' side, still, do citizens perceive that there is not information enough from the public administration. This could for instance be that the information the public administration release is hard to find for the citizens and therefore they need to use a lot of time to get to the searched information.

Another approach the public administrations could use was to nudge the citizens to more energy-friendly habits instead of creating enormous projects which could end unsuccessfully. This could for instance be providing the house owners with data over how they used their energy on a monthly basis and how they could change that through small implementations. This element could also create a better interplay between the public and citizens, however, it should be clear for the public administration that the citizens are willing to change their energy habits. The trust of the citizens could be recreated through successful projects which are in favor of the citizens and therefore it is, important to listen to the concerns of the citizens to create the direction for upcoming projects. Furthermore, it is important to look into the economic part of investments as solar cell panels, because the public administration does not think of the money of the individual and how much they have for certain energy projects especially if it is expensive and their current supply is cheaper than the recommended. Therefore, it is important to illuminate different settlements that could help the citizens to invest in the project, this could for instance be an installment agreement with benefits for the citizen.

The economic perspective could be an area where the public administrations could look into because a change of 500 DKK would not seem as much for them, but for the house owners it could have a major influence, which could end with them choosing a less energy-friendly solution. The economic perspective could also be discussed from the public administrations part because they are forced to do some changes because of the legislation, where they typically have a specified time to reach the specific goal. This could create a grey-zone where the public administration needs to take action to reach a certain goal and therefore realize that they cannot incorporate a small amount as 500 DKK, for the individual, in their accounting.

Through different approaches the public administration can regain the trust of its citizens particularly through workshops, information meetings, economic perspective, etc. It is important to notice that successful projects require better communication and willingness from both parts.

## 9.3 Critical Theory of Technology

This section of the discussion will enlighten how critical theory of technology (CTT) could impact the generated data if it were chosen as the main theory.

CTT does not view technology as a thing neither a neutral object, rather it understands the technology through the contexts and conditions of the design and the power relations it structures. CTT illuminates politics, values and power structures that come along with its technologies, where it democratizes and decentralize the control of the technology which can create equity and promote justice. CTT highlights the technology as not neutral, more something subjective in a values-based context.

CTT highlight two different models of communication, the first one is a technocratic model of control, where the technology is created in isolation from the community and privileging values as authority and expertise. The second model is the democratic model of communication which focuses on democracy and plurality, here it decentralizes the technology which removes the hierarchy. In this study, CTT could have given us a different insight in how the values, hierarchy, and power structures there are in the implementation of heat supply in Fløng.

How can CTT illuminate the hierarchies and the oppressive? It is apparent through the generated empirical data in the report that the municipality has more power than the citizens in Fløng, particularly because of legislation on the heat supply. Therefore, they can override the citizens, when it comes to authority in the municipality, which makes the citizens the oppressed group. This is also apparent in the former project in Fløng with district heating, which ended unsuccessfully. Here the oppressed group did not have the influence they should have had and the municipality overruled them, which ended in a technocratic technology, where the values of the technology came from an isolated authoritarian point, that ended in different value-based socio contextual place and therefore did not make use of the democratized part to decentralize the technology.

This means that CTT could highlight the value-based design in the implementation of district heating in Fløng, which could result in a more successful project. One of the main elements that CTT could highlight could be how the municipality makes use of the legislation and how it could be decentralized and a more democratic model of communication instead of the isolated technogram it could be at the current time. It can also be discussed how the municipality could skirt from overriding the citizens which is the oppressed group because of the legislation and tied up relations they could have to certain areas. This means that the municipality cannot react to certain areas as it intends, because of the goals and legislation there is on the matter. The aforementioned matter could for instance be that the municipality has been given an instruction from the government which proclaims that the municipality should try to nudge the citizens towards a district heating solution, which leaves the municipality without their own solution.

The value-based approach that CTT enlighten could be used as a steppingstone to understanding how the citizens become the oppressed group and how they can deviate from that and create equity and promote justice through the democratic model of communication. Furthermore, CTT maybe could have given us a broader insight into how the technology is developed and why it ends unsuccessfully as district heating in Fløng. ANT highlighted the unstable network there is in such an implementation, whereas CTT could illuminate the hierarchy and power structures (inclusive the oppressive group) there is, and how the values within the technology differs too much to create successful implementation within energy renovation and heat supply. Furthermore, CTT could enlighten the grey-area on the interplay between legislation, municipality, and citizens, hereupon they could create a better understanding between them, and additionally accommodate each other's requirements.

## 10.0 Conclusion

The global climate crisis requires action and if the Paris Agreement is to be complied with, actions are required now. Inspired by the global need of environmental intervention the Danish government has set a goal of reducing greenhouse gas emissions with 70 % by 2030. The national 2030 goal requires municipalities to act.

In Høje Taastrup Municipality the energy consumption among single-family house owners in Fløng are identified by the municipality as an area where potential reduction could be done, as most of the single-family houses are heated by a heat supply based on fossil fuels.

Thus, this master thesis was set out to investigate the following problem statement:

**How can municipal greenhouse gas reduction and energy-saving projects in Fløng, targeted single-family houses, accommodate the needs of the house owners through user involvement, and how can the Municipality of Høje Taastrup improve and promote user involvement.**

Our findings through the generated data were that the economic perspective on energy-friendly initiatives have a dominant influence on the choices of the house owners regarding energy initiatives. This master thesis, therefore, highlights the importance of *alignment* in the network between the municipality and the house owners in Fløng. The creation of successful implementation, opposite the previous project with district heating in Fløng, needs to accommodate the requirement of the citizens and hence be at least as sufficient as their current heating supply. Furthermore, the thesis illuminates the lack of and incoherence in information about energy-friendly implementations and how the public administration needs to recreate the bond of trust between them and citizens considering former changes in duties for solar panels. This master thesis illuminates the unstable network there is in Fløng which could be the reasoning behind unsuccessful implementation and how Michel Callon´s *Four Moments of Translation* highlight various areas, where the network shows instability.

In order to ensure optimized communication, it is necessary to have a representative from the municipality. Furthermore, it is necessary for the citizens that they have some committed house owners to represent the area of Fløng. Lastly, the thesis highlights the importance of expert, which can represent the different solutions for energy renovation and heat supply. This master thesis shed light on the missing of coherent information about the different technologies. Thus, the experts need to communicate and reach consensus, so that they do not provide contradictory information.

## 10.1 Høje Taastrup Municipality

The following section contains a brief description of what initiatives the municipality could take to optimize the interplay with the citizens. According to this, the authors of the thesis created different personas, which could help the municipality to reach the citizens more efficiently. Furthermore, we identified a lack of communication between citizens in Fløng and the municipality, here a representative from the municipality could create an optimized bond with citizens through committed house owners in the area.

Høje Taastrup Municipality could create workshops and information meetings with the citizens and experts on the matter of energy renovation and heat supply to accommodate the needs of the citizens, additionally create a better understanding of which implementations there could occur in the area of Fløng.

The created personas can give the Municipality of Høje Taastrup insights in the house owners in Fløng, hence create a more efficient way to reach the users (house owners). Høje Taastrup Municipality could use the personas given by the authors of this thesis to understand the missing parts of their motivation to implement green energy efficient solutions in accordance with Høje Taastrup Municipality.

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# 12.0 Overview of Appendix

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